IN TWO SECTIONS—SECTION ONE

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ANNUAL MEETING, NEW YORK, DECEMBER 2-5

OCTOBER ~ 1919

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29 WEST 39TH STREET, NEW YORK, U.S.A.

Coming Meetings for October

The Council and Mid-West Sections to Join in Meeting at Indianapolis, Ind.

On Friday and Saturday, October 24 and 25, eight Sections of the Mid-West will hold a joint meeting at Indianapolis, Ind., with sessions on the subjects of Engineering Research and Industrial Unrest. The first meeting of the Council for the new fiscal year will be held at Indianapolis at this time. Special entertainment and inspection trips will be arranged. (For further details see page 847).

Other Section Meetings

Birmingham Section.

October 11: Excursion to the Fairfield Works of the Tennessee Coal, Iron, & Railroad Co., returning for a social dinner meeting at the Southern Club.

Buffalo Section.

October 14: At the Ellicott Club. Subject to be announced later.

Chicago Section.

October 21: "Political Problems," in the rooms of the Western Society of Engineers.

October 29: "Power Supply of the Future," in the rooms of the Western Society of Engineers.

Cleveland Section.

October 27: Subject not yet decided upon. Meeting to be held in the rooms of the Cleveland Engineering Society, Chamber of Commerce Building.

Mid-Continent Section.

October 30: All-day meeting at Bartlesville, Okla.

1. Effect of Compressed Air on Gas or Petroleum Oils, by W. S. Smith of Miller Gas Engine Co., Tulsa, Okla.
2. Gas Pipeline Maintenance, by C. E. Brock, Supt., Gas Pipelines, Empire Companies, Bartlesville, Okla.
3. Problems Confronting Engineering Colleges, by Dean A. A. Potter, of the Kansas State Agricultural College, Manhattan, Kansas.
4. Address by Dr. Ira N. Hollis, President, Worcester Polytechnic Institute, Past President, A.S.M.E.
5. Appraisement of Oil and Gas Properties, by O. J. Berentz, Vice-President, Oklahoma Petroleum and Gasoline Co., Tulsa, Okla.
6. Address by Dr. H. B. Shaw, head of Doherty Training School, New York, N. Y.

New Haven Branch.

October 15: Joint meeting with the Winchester Engineering Club, in the Club rooms. Address by F. O. Williams, General Manager of the Seamless Rubber Co., New Haven, Conn.

Philadelphia Section.

October 28: At the Philadelphia Engineers' Club. Subject not yet decided upon.

San Francisco Section.

October (definite date not yet decided upon): The Flow of Oil in Pipe Lines. Meeting to be held in the rooms of the Engineers' Club.

ENGINEERING COUNCIL

Washington Office

Tenth and G Streets N. W.

To the Members of The American Society of Mechanical Engineers:

The Washington office of Engineering Council was established last January for the benefit of the engineering profession of America. This office is in contact with the various departments of the Government and keeps abreast of legislation relating to matters in which engineers are concerned in connection with the practice of their profession. It endeavors to keep the engineering profession prominently before the legislative and executive branches and seeks to secure the appointment of engineers to all those places which have engineering functions. Finally, it maintains a legislative and departmental service which is supplied to the technical press and to engineers individually. Any engineer who desires a copy of a bill or information upon any bill that is being discussed in Congress, or has need of data of any kind issued by a Government Bureau, has only to ask the Washington office for the information or material. These will be supplied, if available, and no charge will be made.

While many engineers have taken advantage of this information service, the Washington office of Engineering Council is equipped to supply information to a much larger number. It is the desire of Engineering Council to extend the service in order to render the greatest possible aid to the engineers of America. All engineers are invited to use the facilities afforded by the organization at Washington and can be assured that they will receive careful attention and that every effort will be made to meet to the fullest extent any demands that may be made.

M. O. Leighton, *Chairman*,
National Service Committee.

Centrifugal Compressors[1]

By GUSTAV FLUEGEL, D. ENG.

For a period of more than four years German engineering and scientific periodicals have been received in this country only to a very limited extent, and American engineers have been unable to follow the technical developments in Germany. Meanwhile the same urgent necessity which inspired the development of new ideas on the Allied and American side during the years of the war has existed also on the German side, with the result that many important and interesting inventions, improvements and researches have been carried out. The American Society of Mechanical Engineers has made a vigorous effort to collect copies of the German periodicals, particularly of the Zeitschrift des Verein Deutscher Ingenieure, and hopes within the limits of the available space to bring to the readers of Mechanical Engineering some of the more important of the German developments, either in the Engineering Survey section or as separate articles. The investigation of the characteristic curves of centrifugal compressors by Dr. Gustav Fluegel, printed below, is but the first installment of what is hoped will develop into a series of articles, abstracts, and translations.

I BASIC CHARACTERISTICS

The characteristic curves of centrifugal pumps and water turbines may be derived in accordance with comparatively simple laws when certain data are available and certain conditions maintained, but the relations are far more complicated in the case of centrifugal machinery for handling elastic fluids. It is due to this fact, in the opinion of the author, that no general formulæ defining the behavior of multi-stage centrifugal compressors are available in technical literature, notwithstanding their great importance.

The characteristic curve of a compressor, that is, the curve which for the same speed of rotation n defines the rise of pressure as a function of the suction volume, can be considered as a result of superposition of the characteristics of all the single stages. If all such single-stage curves for the same speed of rotation and the same initial state be plotted in some system of coördinates, one obtains a group of curves such as shown in Fig. 1; and, as a rule, the nearer the stage is to the compressor end the smaller is the volume of fluid q flowing through it and the delivery head Δp. In a similar manner could be plotted the efficiency curves, which are different for every individual stage. The whole system of curves varies with the speed of the compressor and with the density of the fluid handled, but this variation of curves may be simplified in what the author calls an extraordinary manner, as will be shown later.

The delivery head Δp for a single stage can be expressed by the known formula

$$\Delta p = m \frac{\gamma}{2g} u^2$$

where m is the value of pressure rise which varies with the angle of blades and for the same angle may be considered as constant, though strictly it increases with the speed in revolutions (regarding which more will be said in another place), u is the peripheral velocity of the pumping wheel, γ the specific weight of fluid at entrance to the wheel and g the acceleration due to gravity.

The compressor is always built for a certain normal output at a normal speed in revolutions n_0 at which it should reach its maximum efficiency. In such a case the admissions of the single stages are equal to unity and the amount of fluid passing therethrough per second is Q_0. With the same speed in revolutions n_0 but with a different amount of fluid passing therethrough, the admission is

$$\varepsilon = \frac{Q}{Q_0}$$

When, however, the speed in revolutions varies also, the same magnitude is expressed by

$$\varepsilon = \frac{Q}{Q_0} \frac{n_0}{n}$$

With the same admission the entrance and exit triangles for the same stage are similar. Hence one may, instead of representing the delivery head Δp as a function of the amount of fluid flow Q, represent the magnitude of the delivery head m of each individual stage as a function of its admission ε, Fig. 2, in which case the curves $A_1 B_1$, $A_2 B_2$, etc., are obtained, and all of them differ but

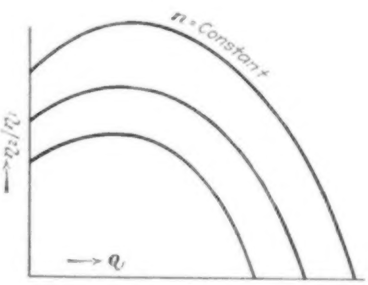

FIG. 1 CHARACTERISTIC CURVES OF A COMPRESSOR (AS A WHOLE)

little from each other because of the fact that all stages in a compressor are usually built very similar to each other. It is therefore natural to plot in their stead an average curve AB, derived from the following point of view. If, at a certain speed in revolutions n of the compressor and peripheral velocity of a wheel u, the value of $S = \Sigma u^2$, then for the stages under consideration can be calculated and for each of the curves $A_1 B_1$, $A_2 B_2$ can be found the corresponding value

$$\gamma_1 = \frac{u_1^2}{S}, \quad \gamma_2 = \frac{u_2^2}{S}$$

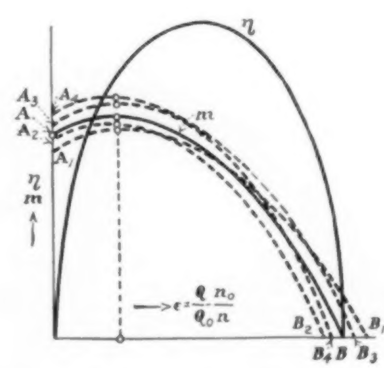

FIG. 2 DELIVERY-HEAD ADMISSION AND DELIVERY-HEAD EFFICIENCY CURVES

If now m_1, m_2, etc., be the numerical values of the pressure head with certain admission ε^1, the average value for the whole group is found to be

$$m = \Sigma \gamma m^1$$

By repeating such determinations as above for a number of admissions, one finds the average curve AB. In a similar manner may be determined as a function of ε the average curve of efficiency η for the single stages.

These two average curves of m and η derived of functions of ε the author calls the *basic characteristic* of a multi-stage compressor group. They are independent of the speed of rotation in revolu-

[1] From *Zeitschrift des Vereines deutscher Ingenieure*, no. 20, vol. 63, May 17, 1919, pp. 455-460.

THE ANNUAL MEETING

New York, December 2-5

A timely and varied program for the Annual Meeting has been arranged by the Committee on Meetings and Program. Besides several general sessions at which technical papers will be presented, the Committee has designated the following major topics for discussion:

Industrial Relations. Keynote session on the general subject of The Industrial Situation in Relation to Present Conditions, with papers and addresses on Systems of Wage Payment, Rights of Workers, Systems for Mutual Control of Industry, and Profit Sharing.

Fuels. A continuation of the discussion on this subject at Detroit. Pulverized fuel in cement kilns and fuels of various kinds of power plants to be included topics.

Appraisal and Valuation Methods. Many members have expressed a desire for a thorough consideration of appraisal methods at a meeting of the Society. It is proposed to present papers on certain phases of the subject at this meeting.

Machine Shop Practice and Foundry Practice. Papers will be offered by the Sub-Committees on these subjects.

Education for the Textile Industry. Session under the auspices of the Textile Sub-Committee.

Internal-Combustion Engines. Papers on heavy-oil engines and gasoline engines, contributed by the Gas Power Sub-Committee.

Engineers who expect to contribute papers to the general sessions, or who have suggestions of papers or authors for the special sessions mentioned above, should advise the Secretary at once in order to secure consideration for the program.

Suggestions Desired for Sections Meetings

To assist the various Sections and Student Branches of the Society in the arrangement of programs for their meetings a list is being compiled of speakers, subjects and papers of technical or civic interest. Please forward your suggestions to headquarters on the attached blank.

SUGGESTIONS FOR A. S. M. E. MEETINGS

Subject {Meeting / Symposium / Session} ....

Speaker ....

Address ....

Title of Manuscript ....

Author ....

Address ....

Are you in a position to assist us in securing this {speaker / manuscript} ....

Where and when, if ever, has the {address / paper} been {delivered / published} ....

Remarks: ....

....

Centrifugal Compressors[1]

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For a period of more than four years German engineering and scientific periodicals have been received in this country only to a very limited extent, and American engineers have been unable to follow the technical developments in Germany. Meanwhile the same urgent necessity which inspired the development of new ideas on the Allied and American side during the years of the war has existed also on the German side, with the result that many important and interesting inventions, improvements and researches have been carried out. The American Society of Mechanical Engineers has made a vigorous effort to collect copies of the German periodicals, particularly of the Zeitschrift des Verein Deutscher Ingenieure, and hopes within the limits of the available space to bring to the readers of Mechanical Engineering some of the more important of the German developments, either in the Engineering Survey section or as separate articles. The investigation of the characteristic curves of centrifugal compressors by Dr. Gustav Fluegel, printed below, is but the first installment of what is hoped will develop into a series of articles, abstracts, and translations.

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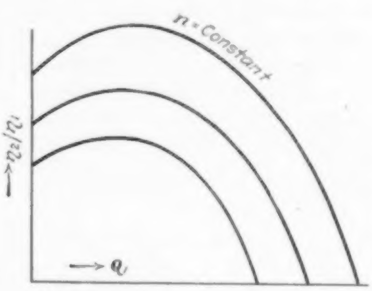

Fig. 1 Characteristic Curves of a Compressor (as a Whole)

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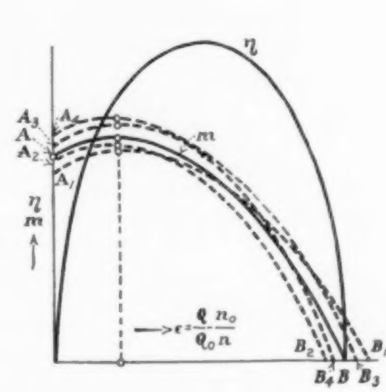

Fig. 2 Delivery-Head Admission and Delivery-Head Efficiency Curves

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tions, or the amount of fluid flowing per unit of time, of the density of the medium handled and of the location of each individual stage, and therefore may be used as a starting point for determining the general behavior of turbo-compressors. Since the individual stages of all centrifugal compressors are built in a manner very similar to each other and since in practice the variation in the speed of rotation, velocity of flow, and delivery head of a compressor is comparatively small, a single basic characteristic ought to be sufficient as a foundation for all calculations, at least when applying to machines of similar design.

II COMPRESSOR WITH UNCOOLED CASING

(a) Compression in a Single Multi-Stage Group

When a considerable rise of pressure is desired, compressors without external cooling are always divided into several groups of stages with intercooling of air between the groups. It is therefore only necessary to investigate the behavior of a single group of stages due to variation of the speed of rotation in revolutions, the amount of fluid flowing through and the initial state of the air. With normal load the admission in all stages is $\varepsilon = 1$, and without impairing materially the precision of results one may consider the magnitude of the pressure head m and the efficiency η of all stages of the group as constant. Under different conditions of operation, however, the values of ε, m and η may vary from stage to stage. From

$$\Delta p = m \frac{\gamma}{2g} u^2$$

we find with sufficient precision for our purposes the following expression for the work consumed in compressing the air in each stage.

$$\Delta E = A \frac{V \Delta p}{\eta} = \frac{A G}{2g} \frac{m}{\eta} u^2$$

where A is the mechanical equivalent of heat; V the amount of air flowing per second and $G = V\gamma$ the weight of air flowing per second. Since, further,

$$\Delta E = G c_p \Delta T$$

when ΔT is the rise of temperature in the stage and c_p the specific heat of the gas, it follows that

$$\Delta T = \frac{A}{2g c_p} \frac{m}{\eta} \Delta s$$

where $\Delta s = u^2$. Further, it has been shown (*Zeitschrift des Vereines deutscher Ingenieure* 1918, p. 662), that

$$\Delta T = \frac{k-1}{k\eta} \frac{\Delta p}{p} T$$

when p is the absolute pressure, T the absolute temperature at the entrance to the stage and k the exponent in the adiabatic equation. This equation was derived by considering the compression as if it were occurring not in a finite number of stages but in an infinite number of very small stages. Because of this the above two relations may be expressed in the form of differential equations

$$\frac{dT}{T} = \frac{k-1}{k\,\eta} \frac{dp}{p}$$

$$dT = \frac{A}{2\,g\,c_p} \frac{m}{\eta} ds$$

If great precision in calculation is desired it is necessary in the integration of these equations to consider only the variation of m and η under normal load by assuming that

$$\eta = \eta_1 = k_1 T$$

$$\frac{m}{\eta} = \left(\frac{m}{\eta}\right)_1 + k_2 s$$

where k_1 and k_2 are constants and $s = \Sigma u^2$ from the first stage to the stage under consideration. The integration gives then the following solutions for the entire group of stages

$$\frac{T_2}{T_1} = \frac{(1+a)\left(\frac{p_2}{p_1}\right)^c}{1 + a\left(\frac{p_2}{p_1}\right)^c}$$

$$T_2 - T_1 = \frac{A\ S}{4\ g\ c_p}\left[\left(\frac{m}{\eta}\right)_1 + \left(\frac{m}{\eta}\right)_2\right]$$

provided the following substitutions are made

$$a = \frac{\eta_2 - \eta_1}{2} \frac{T_1}{T_2}$$

$$c = \frac{k-1}{k\,\eta_1}$$

and $S = \Sigma u^2$ for all stages of the group. The subscript 1 denotes the values for the entrance to the group and the subscript 2, exit from the group.

Since, however, no especially great precision is necessary for purposes of general calculation in practice, approximations may be sufficient and it is permissible to substitute in the integration for m and η constant average values m_m and η_m. This gives

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^c \qquad \text{[1]}$$

where

$$c = \frac{k-1}{k\ \eta_m}$$

and

$$\frac{A\ S}{2\ g\ c_p\ T_1}\left(\frac{m}{\eta}\right)_m = \frac{T_2}{T_1} - 1 \qquad \text{[2]}$$

The value of S is to the value of S_0 at the normal speed in revolutions n_0 in the ratio of $\frac{S}{S_0} = \left(\frac{n}{n_0}\right)^2$. With the aid of Equation [2] may be found for various values of m_m and η_m the corresponding temperature ratios T_2/T_1 for constant value of S and hence, in accordance with Equation [1], the ratios of compression p_2/p_1, or, inversely, with the constant compression ratio the respective values of S, that is, speeds in revolutions. The average values of m_m and η_m can be derived from the fundamental characteristic curves, Fig. 3, in accordance with the following procedure. If ε_1 denotes the admission of the first and ε_2 of the last stage, then the average admission of the group is

$$\varepsilon_m = \frac{\varepsilon_1 + \varepsilon_2}{2}$$

The values corresponding to m_m and η_m corresponding to Σ_m are next inserted in Equation [2]. Attention is called here to the fact that the actual average values of m and η lying between ε_1, and ε_2 differ somewhat from m_m and η_m because of the curvature of the curves, the more so the more there is difference between ε_1 and ε_2. This circumstance may, however, be taken into consideration in inserting these values into Equation [2], and estimated variations in the values made.

Let subscript o denote the relations existing at normal load, subscript 1 the entrance to the compressor group and subscript 2 the exit therefrom. Further, let G be the weight of air flowing through the unit per second. Then the following values obtain for ε_1 and ε_2

$$\varepsilon_1 = \left(\frac{Q}{Q_0}\right)_1 \frac{n_0}{n} = \frac{G}{G_0}\left(\frac{p_0}{p}\ \frac{T}{T_0}\right)\frac{n_0}{n},$$

$$\varepsilon_2 = \left(\frac{Q}{Q_1}\right)_2 \frac{n_0}{n} = \frac{G}{G_0}\left(\frac{p_0}{p}\ \frac{T}{T_0}\right)_0 \frac{n_0}{n}.$$

Hence

$$2\varepsilon_m = \varepsilon_1 + \varepsilon_2 = \varepsilon_1\left[1 + \left(\frac{p_2}{p_1}\ \frac{T_1}{T_2}\right)\frac{p_1}{p_2}\ \frac{T_2}{T_1}\right],$$

$$\varepsilon_1 = \frac{2\varepsilon_m}{1 + \left(\frac{p_2}{p_1}\ \frac{T_1}{T_2}\right)_0 \frac{p_1}{p_2}\ \frac{T_2}{T_1}}.$$

The volume of air taken in by suction is then

$$Q_1 = \varepsilon_1 Q_{01} \frac{n}{n_0}$$

or

$$Q_1 = Q_{01}\,\frac{2\varepsilon_m \dfrac{n}{n_0}}{1+\left(\dfrac{p_2}{p_1}\,\dfrac{T_1}{T_2}\right)\dfrac{p_1}{p_2}\,\dfrac{T_2}{T_1}} \qquad [3]$$

The work of compression consumed by the group is

$$E = G\,c_p\,(T_2 - T_1) \qquad [4a]$$

and it has been shown in a previous paragraph that

$$\Delta E = \frac{A\,G}{2\,g}\,\frac{m}{\eta}\,u^2.$$

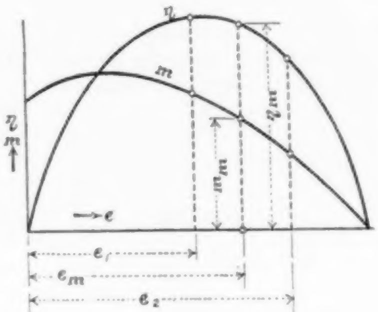

Fig. 3 Basic Characteristic Curves, Compressor with Uncooled Casing

From these the following further equation is obtained, namely,

$$E = \frac{A\,G\,S}{2\,g}\left(\frac{m}{\eta}\right)_m \qquad [4b]$$

which must give for E the same value as Equation [4a]. In order to evaluate the main equations more uniformly the temperature relation

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^c = \frac{E}{G\,c_p\,T_1} + 1$$

can be expressed as a function of the pressure ratio p_2/p_1 for the various values of c, that is, of η_m = constant. In this way Equation [1] will be graphically reproduced. The characteristic curve of the group is then determined in a simple manner, as follows:

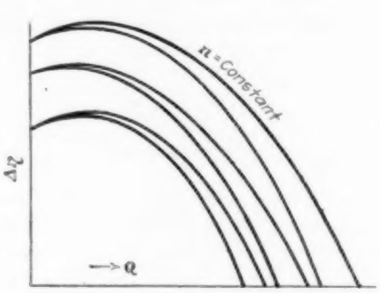

Fig. 4 Characteristic Curves for the First Group of Stages of a Compressor

In Equation [2] are inserted the values of $\left(\frac{m}{\eta}\right)_m$ corresponding to the various values of Σ_m for the same value of n, (that is, for S = constant). Thereby may be determined the corresponding values of T_2/T_1 and hence the values of p_2/p_1. In this manner all the magnitudes on the right side of equation 3 are determined and the volume of the air taken in by suction Q_1 may be calculated. When this is done the compression ratios p_2/p_1 may be plotted as a function of Q_1, as in Fig. 4, which determines the first group characteristic curves. In a similar manner the other group characteristic curves may be computed for other speeds in revolutions n.

The problem may be therefore considered as solved for multistage compressors without intercoolers.

(*b*) Total Compression of Compressor

If a group of stages is followed by an intercooler, the amount of heat taken away from the flowing air can be in the first approximation expressed by

$$W = Gc_p(t_2 - t_1) \cong kF\frac{t_2 - t_k}{2}$$

where t_2 is the entrance temperature and t_1 the temperature at the exit from the cooler and t_k the average temperature of the cooling water, k the coefficient of heat transmission and F the area of the cooler. Since, in intercoolers, by far the greatest resistance to heat flow from air occurs at the tube wall and since practically all factors except the velocity of flow c and the density γ are constant, k can be expressed as follows:

$$k = k^1(c\gamma)^q$$

where k^1 and q are constants. Because of the constant magnitude of the cross-section of flow of air, $c\gamma$ is proportional to the weight of the flowing air G and therefore

$$k = k_0\left(\frac{G}{G_0}\right)^q$$

where k_0 is the coefficient of heat transmission at normal load.

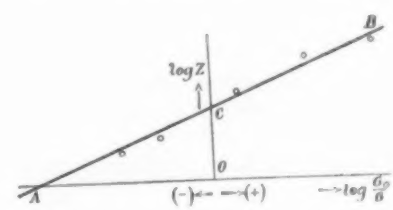

Fig. 5 Graphic Referring to Equation [18]

If K be used to denote all the constants, the above heat equation can be written as follows:

$$G_0(t_2 - t_1)_0 = KG_0{}^q(t_2 - t_k)_0 \text{ at normal load}$$
$$G(t_2 - t_1) = KG^q(t_2 - t_k) \text{ at any load}$$

From these two equations it is found that

$$t_1 = t_2 - \left(\frac{G_0}{G}\right)^q \left(\frac{t_2 - t_1}{t_2 - t_k}\right)_0 (t_2 - t_k) \qquad [5]$$

This determines the absolute temperature $T_1 = 278 + t_1$ at the entrance to the next group of stages. As regards q, in well-designed coolers one can use with fair approximation the value 0.78, which has been found by Nusselt to be good under different circumstances. The fall of pressure Δp in the intercooler varies in proportion to the average density γ and also in proportion to the square of the amount of air flowing per second Q

$$\frac{\Delta p}{\Delta p_0} = \left(\frac{Q}{Q_0}\right)^2 \frac{\gamma}{\gamma_0} \qquad [6]$$

This establishes all the factors necessary for the calculation of the characteristics of compressors which may be determined in the following manner:

(1) It is necessary to determine for each group of stages a set of group characteristic curves in accordance with Fig. 4.

(2) For a given speed of rotation and volume of flow the state of the air at the exit from the first group of stages can be determined from the corresponding group characteristic curve which permits to determine the state of air at the entrance to the second group by the application of Equations [5] and [6]. In this manner Q_1 for the second group becomes known.

(3) Next, the same process as in (2) is applied to the second group with the intercooler following it and so on until the last group, which permits the determination of the final state of air for a given speed of rotation and amount of flow of air.

(4) The final state of air may be determined in the same manner for the same speed of rotation and different amounts of air flowing, which gives the first characteristic curve of the compressor. In a similar manner other characteristic curves for different speeds

of rotation may be determined. The total work of compression is then

$$E_s = Gc\, \Sigma (T_2 - T_1) = \frac{AG}{2g} \Sigma \left[S \left(\frac{m}{\eta} \right)_m \right] \ldots\ldots\ldots [7]$$

Instead of this rather complicated process there is a simpler way to secure the same results with sufficient approximation. Since it is desirable to have the same work of compression in all groups of stages of a compressor, and in practice an effort is always made to secure it, it may be assumed that this actually takes place and that further all the groups have the same air temperature at the entrance and the same conditions of compression. If then,

T_1 = average absolute air temperature at the entrance (arithmetic average of the actual temperatures at the entrance to each individual group of stages), which, with constant cooling-water temperature, varies only very little with the load, and may be estimated

T_2 = absolute average temperature at exit from the groups of stages

T = average absolute temperature at the entrance to the first group of stages

T_{II} = average absolute temperature at the exit from the last group of stages

$\frac{p_2}{p_1}$ = average compression ratio of a single group

p^I = absolute pressure ahead of the first group of stages

p_{II} = absolute pressure behind the last group of stages

i = number of groups of stages

Then the total compression ratio is in the usual manner found to be

$$\frac{p_{II}}{p_I} = \left(\frac{p_2}{p_1} \right)^i$$

The actual end temperature is found from

$$\frac{T_{II} - T_I}{T_2 - T_1} \cong \left(\frac{T_{II} - T_I}{T_2 - T_1} \right)_0$$

and proves to be

$$T_{II} = T_I + (T_2 - T_1) \left(\frac{T_{II} - T}{T_2 - T_1} \right)_0$$

According to the above assumption all the groups of stages are to be considered as equivalent. Because of this, Equation [2] may be applied to the case of one group in the following manner

$$\frac{AS_s}{2igc_pT_1} \left(\frac{m}{\eta} \right)_m = \frac{T_2}{T_1} - 1 \ldots\ldots\ldots\ldots\ldots\ldots [8]$$

but in this case $S_s = \Sigma u^2$ applies to the entire compressor. If we assume various values for the average admission, this equation by means of Equation [1] may be evaluated in exactly the same manner as Equation [2]. It must be observed in this connection that here the average admission ε_m is the average of the admissions ε_I of the first stage of the first group and ε_I of the last stage of the last group, these two magnitudes being determined from the following equations:

$$\varepsilon_I = \left(\frac{Q}{Q_0} \right)_I \frac{n_0}{n} = \frac{G}{G_0} \left(\frac{p_0}{p} \frac{T}{T_0} \right)_I \frac{n_0}{n}$$

$$\varepsilon_{II} = \left(\frac{Q}{Q_0} \right)_{II} \frac{n_0}{n} = \frac{G}{G_0} \left(\frac{p_0}{p} \frac{T}{T_0} \right)_{II} \frac{n_0}{n}$$

where the subscript 0 corresponds again to the conditions existing with normal loading.

From these equations is derived the following equation, which takes the place of Equation [3]

$$Q_1 = Q_{0I} \frac{2\varepsilon_m \frac{n}{n_0}}{1 + \left(\frac{p_{II}}{p_I} \frac{T_I}{T_{II}} \right)_0 \frac{p_I}{p_{II}} \frac{T_{II}}{T_I}} \ldots\ldots\ldots\ldots [9]$$

Just as in the preceding case, from Equations [8] and [9] may be derived the compressor characteristics instead of the group characteristics. Equation [5] may be used to check the assumed value of T_1 since $t_2 - t_1 = T_2 - T_1$.

The total work of compression is

$$E_s = G\, c_p\, i\, (T_2 - T_1) = \frac{A\, G\, S_s}{2g} \left(\frac{m}{\eta} \right)_m \ldots\ldots [10]$$

To this should be added two small amounts to cover the losses through rotor friction and those due to leaks on the pressure side; these losses vary in accordance with laws of their own. Practice indicates that the work consumed in rotor friction of a stage is proportional to $\gamma\, n^3 D^5$, where D is the diameter of the rotor, while the loss due to leaks depends on the final state of the gas in accordance with well-known laws.

(c) Determination of the Basic Characteristic from a Given Compressor Characteristic

According to the reasoning given in Section I, the basic characteristic can be determined when the characteristics of all single stages have been found. Since, however, this is never the case, another method may be resorted to, viz., reversing the problem solved in Section II(b), and determining the compressor characteristic from the basic characteristic. Since, for a given load, the entrance and exit temperatures for each group, and, as a rule, also the total work of compression E_s, may be measured with sufficient approximation, it is possible to calculate the average entrance temperature T_1, as well as the sum of all the raises in temperature $\tau = \Sigma\, (T_2 - T_1)$, and, hence, the average raise of temperature per group

$$T_2 - T_1 = \frac{\tau}{i} = \frac{E_s}{i\, G\, c_p}$$

The average compression ratio of a group is

$$\frac{p_2}{p_1} = \left(\frac{p_{II}}{p_I} \right)^{\frac{1}{i}}$$

And, hence, when the ratios T_2/T_1 and p_2/p_1 are known, the average efficiency η_m of a single stage may be determined from the relation

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1} \right)^c$$

Equation [8] makes it possible to determine the magnitude of the pressure head m_m if S_s is given. If, further, a certain load be taken as a normal load so that with it the admission in all the stages is $\varepsilon = 1$ and all the corresponding magnitudes are indicated by a subscript 0, then the corresponding average admission ε_m may be calculated from Equation [9]. By this are determined the exact locations of the points ε_m, m_m and η_m of the basic characteristic. Similarly the corresponding basic characteristic can be determined from a group characteristic.

III COMPRESSOR WITH COOLED HOUSING

(a) Compression in One Group of Stages

As in the case of compression with uncooled housing, the writer uses an equation derived by him elsewhere (*Zeit. Ver. deut. Ing.*, 1918, p. 662) under the assumption of the presence of an infinite number of stages and in this way derives the following relation for the temperatures

$$T_2 = \frac{M}{1 + \frac{a}{b} \frac{T_1}{T_K} (M - 1)} \ldots\ldots\ldots\ldots\ldots [11]$$

wherein for the sake of simplicity is substituted

$$M = \left(\frac{p_2}{p_1} \right)^{bc}$$

and further, the following expressions are used in which minor members are neglected

$$a = \frac{kFT_k}{E}$$

$$b = 1 + a$$

$$c = \frac{\kappa - 1}{\kappa \eta_m}$$

Here $k = k_0 \left(\frac{G}{G_0} \right)^q$, the average coefficient of heat trans-

mission k_0 having the value which it has at normal load; because of the greater resistance to heat flow q is here smaller than in the case of intercoolers with smooth thin brass tubes. Also F = cooling area of the group and T_k = average temperature of the cooling water.

In accordance with the previous derivation by the same author referred to at the beginning of this section, the work of compression of the group is

$$E = \frac{Gc_pT_K}{a}\log\left[1+\frac{a}{b}\frac{T_1}{T_K}(M-1)\right] \qquad [12]$$

Further, as in the case of compression in an uncooled cooler

$$E = \frac{AGS}{2g}\left(\frac{m}{\gamma}\right)_m \qquad [4b]$$

By combining these two equations we get

$$V = \log\left[1+\frac{a}{b}\frac{T}{T_K}(M-1)\right]$$

where for simplicity sake is substituted

$$V = \frac{aAS}{2gc_pT_K}\left(\frac{m}{\gamma_m}\right)$$

The equation can also be written in the form

$$\frac{b}{a}\frac{T_K}{T_1}\left[e^V-1\right] = M-1 \qquad [13]$$

If now in the expression $a = \frac{kFT_K}{E}$ be inserted the expression for the coefficient for heat transmission k as given by Equation [4b], we obtain

$$a = \frac{2gk_0FT_K}{AG_0S\left(\frac{m}{\gamma}\right)_m}\left(\frac{G_0}{G}\right)^{1-q} \qquad [14]$$

Further, Equation [3] applies here without alterations, only instead of the volume of flow of air, the author uses in this case the weight of the flowing air which gives that equation the form

$$\frac{G}{G_0} = \frac{2\varepsilon_m\frac{n}{n_0}\left(\frac{p}{p_0}\frac{T_0}{T}\right)_1}{\left(\frac{p_2}{p_1}\frac{T_1}{T_2}\right)_0\frac{p_1}{p_2}\frac{T_2}{T_1}} \qquad [15]$$

These equations are sufficient for determining the usual characteristic from a given basic characteristic. Since, however, some of these equations appear in a transcendent form, the problem cannot be solved directly and to assist in this the author derives a very useful additional formula in the following manner:

The expression

$$\Delta p = m - \frac{\gamma}{2g}u^2$$

may be written in the form of a differential, as follows:

$$dp = \frac{m}{2g}\frac{p}{RT}ds,$$

when R is a gas constant and $ds = d(u^2)$. Its integration gives

$$\log\frac{p_2}{p_1} = \frac{m_mS}{2gRT_m} \qquad [16]$$

where $m = m_m$ = constant and likewise $T = T_m$ =constant. This simple relation applies, of course, to the case of compression in an uncooled casing also, but there is no need for making use of it there.

Given two of the values $\frac{p_2}{p_1}$, ε_m (that is, m_m) and H (that is, n), the third value can be easily plotted. With constant average admission ε_m of the group, the average temperature T_m increases somewhat with the speed of rotation and falls off with the decrease of the speed of rotation. Since, however, T_m may be calculated from a given characteristic corresponding to the speed of rotation in revolutions n_0 in accordance with an equation for the admission ε_m, T_m can be estimated with fairly close approximation for any other speed in revolutions.

Hence, from Equation [16] we may compute, for various values of the average admission ε_m, either the corresponding compression ratios p_2/p_1 for a constant speed of rotation in revolutions, or the corresponding speeds of rotation in revolutions for a constant compression ratio.

Equation [15] enables us to determine the relation G/G_p by using an estimated value of the end temperature T_2. The same rule applies to it as to T_m, namely, that for a constant admission ε_m it varies in the same sense as the speed of rotation in revolutions (with an uncooled casing $T_2 - T_1$ is proportional to S, that is, the square of the speed of rotation in revolutions; with the cooled casing $T_2 - T_1$ varies somewhat less). Since a given characteristic for n_0 and ε_m gives the end value T_2 it may be equally well estimated for any other speed of rotation in revolutions, and with this the value of a can be determined from Equation [14]. The values thus obtained must satisfy Equation [13] and it is well to compute from ε_m, S and a, also first M and then the compression ratio $\frac{p_2}{p_1}$, which should agree with that derived from Equation [16]. Finally, from Equation [11] can be computed the temperature relation T_2/T_1 which should agree within fairly close limits with that obtained by estimation from Equation [15]. Likewise one may plot, as has been done in the compression with an uncooled vessel, the function

$$M = \left(\frac{p_2}{p_1}\right)^{bc}$$

for various sufficiently closely located values of bc = Constant as a function of $\frac{p_2}{p_1}$. This gives for the case of a compressor with the cooled housing a solution of the problem of deriving the group characteristics of Fig. 4 from a given basic characteristic.

(b) Total Compression in a Compressor

If the compressor is divided into two or more groups of stages separated by intercoolers, then the computation may be carried on from group to group in the above described manner by determining the back cooling and the fall of pressure in the intercooler following each group of stages (by using Equations [5] and [6]; it must be noted however that the exponent q in the case of an intercooler is different than when used for housing of the condenser. There is, however, a shorter method for the computation of the characteristic curves of a compressor based on the assumption that all the groups of stages are equivalent to each other. The corresponding relations set forth in Section II (b) are applied in this also. Hence, here also the total ratio of compression is

$$\frac{p_{II}}{p_I} = \frac{p_2}{p_1}$$

and the end temperature

$$T_{II} \cong T_I + (T_2 - T_1)\left(\frac{T_{II} - T_I}{T_2 - T_1}\right)_0$$

Equations [11] to [16] apply here also, but the values

$$S = \frac{S_s}{i}$$

$$E = \frac{E_s}{i}$$

$$F = \frac{F_s}{i}$$

must be used, if $S_s = \Sigma u^2$ applies to the entire compressor and E_s represents the total work of compression while F_s represents the total cooling area of the compressor. Further, instead of the coefficient of heat transmission k_c there should be used here its average value for the entire compressor. Equation [15] is to be used here in the form

$$\frac{G}{G_0} = \frac{2\varepsilon_m\frac{n}{n_0}\left(\frac{p}{p_0}\frac{T_0}{T}\right)_1}{1+\left(\frac{p_{II}}{p_I}\frac{T_I}{T_{II}}\right)_0\frac{p_I}{p_{II}}\frac{T_{II}}{T_I}} \qquad [17]$$

which corresponds to Equation [9] if the weight of the flowing air be used instead of the volume of said air. The method of computation is the same as in III-a.

(Concluded on page 858)

Certification of Gages at Bureau of Standards

By H. L. VAN KEUREN,[1] WASHINGTON, D. C.

During the early stages of the preparation for war in this country the need of a central bureau for the test and certification of munitions gages was apparent. Action was taken by the Committee on Standardization of Gages of The American Society of Mechanical Engineers in recommending to various branches of the War and Navy Departments that there be a central place for the inspection of munitions gages and that inasmuch as the Bureau of Standards was already prepared for this work, it be the recognized institution for the inspection of all gages required by the Government in securing munitions. Since the signing of the armistice the Bureau has been continuing its work of gage certification for manufacturers in the production of their regular products and it has already become an important element in this country.[2] In the following contribution Mr. Van Keuren, Chief of Gage Section, Bureau of Standards, gives an account of the work and methods of this department.

THE war has changed in a radical way many of our ideas, habits, words and expressions, as well as many of our commercial and industrial methods. Today we speak of the certification of gages rather than the certification of standards. To the manufacturing public a gage is the usable thing; the standard is for reference. The time is long past when people need be inconvenienced by carrying and using silver dollars as a measure for the value of their purchases but they use instead, as their working medium, the convenient paper bills or checks, which are directly or indirectly certified by a standard value in silver or gold money in the custody of one of our banks or the United States Treasury. In the same way it is not necessary for manufacturers of interchangeable work to be burdened with an elaborate system of measuring devices and a highly-trained scientific organization for originating and comparing precision length standards; but rather, for convenience and rapidity, they use gages for measuring their product and these gages may be authenticated by being referred directly or indirectly to suitable standards in the custody of the Bureau of Standards.

As a result of the war even our ideas of standards have been radically changed. We now use a standard of length which cannot change with time; one which can be duplicated anywhere in the world; one which cannot be stolen, lost or destroyed; and one which is susceptible to greater accuracy of measurement than the standard meters or yards deposited in goverenment institutions in this country or in foreign countries. I refer to the use of the length of a wave of light which makes length measurements to within a millionth of an inch an easy matter.

Organization and Facilities of the Gage Section, Bureau of Standards

On June 15, 1917, the Bureau of Standards was granted an appropriation by Congress for the purpose of standardizing and certifying gages for the War and Navy Departments and other branches of the Federal government. As early as July 8, 1917, apparatus and equipment was transferred to a special building for the testing of munition gages. The first lot of gages was submitted on June 16, 1917. In addition to the laboratory in Washington, Branch Gage Sections were inaugurated as rapidly as need became apparent. The Branch Gage Section in New York City was opened on April 15, 1918; the Branch Gage Section in Cleveland on July 1, 1918; and the Branch Gage Section in Bridgeport on August 20, 1918.

The gage laboratories at Washington, New York and Cleveland are completely equipped, and the facilities in the branch laboratories for the inspection of gages are practically the same as those available in Washington.

A general view of the Gage Laboratory at Washington, showing the testing of plain and profile gages, is shown in Fig. 1. The equipment includes various types of commercial measuring instruments, such as inside and outside micrometers; a number of sets of working standards of the flat-end type, cylindrical type and spherical-end type; and other devices and instruments designed and constructed at the Bureau for the measuring of complicated profile gages and thread gages.

Routine of Inspection Work

In the inspection of gages at the Bureau, the following procedure has been adopted:

- *a* Unpacking and checking with shipping memorandum
- *b* Marking with a lot number and serial number
- *c* Acknowledgment of receipt
- *d* Routing for test
- *e* Measurement
- *f* Tabulation of results and comparing results with specifications
- *g* Mailing report
- *h* Ship or stock gages.

Particular care is taken in the various operations in checking and measuring the gages and in writing the reports in order to prevent mistakes. During each test measurements are made on a gage by two inspectors who work independently. The results obtained by each inspector are entered on a suitable form and from the records of both inspectors the results of the test are compared with the specifications upon which the gage was purchased, or with which the gage is supposed to correspond. In case of tests for the War Department, gages which meet the specifications, are marked with a seal and date of approval. If rejected, they are returned to the manufacturer with a report stating the reasons for rejection, in order that corrections may be made or new gages submitted.

The importance of two inspections by different people, oftentimes employing different methods, cannot be over-estimated. Not only is it possible to avoid numerous errors of reading but differences in results are sometimes found to be due to actual variations in the apparatus, which results in the development of new and improved methods of measurement and new measuring appliances.

Methods of Test

The apparatus in use and the methods of test have been selected with the object of obtaining the required accuracy of test, and at the same time reducing to a minimum the time required in testing the gages. As an illustration of a simple, effective, accurate and quick device for testing snap gages, the apparatus shown in Fig. 2 has been used with excellent results. In carrying out this test, one or two standardized size blocks are selected to permit the insertion of a pair of accurately-ground and lapped wedges, which, when placed together, have their contact surfaces parallel. With a calibrated micrometer the thickness of the adjustable wedge is determined and then added to the size block selected, which results in the measurement of the gage being inspected.

To describe all of the devices, methods and apparatus in use is quite beyond the scope of the present paper. However, the following outline indicates the more important pieces of apparatus used for gage inspection:

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[1] Chief of Gage Section, Bureau of Standards, Washington, D. C. Mem. Am.Soc.M.E.

[2] A detailed statement of the work of this committee and its recommendations can be found in THE JOURNAL, January 1918, p. 70. The extent to which the recommendations were carried out, the opportunities afforded and results accomplished by the Bureau of Standards is given in detail in THE JOURNAL for February, 1919, p. 185. This paper was presented at the meeting of the Washington Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, April 30, 1919.

A Plain gages, outside dimensions
1 Calibrated micrometer calipers
2 Special Anderson bench micrometer, accurate to 1/100,000 in.
3 Commercial fluid-gage comparator
4 Pratt & Whitney measuring machine
5 Brown & Sharpe measuring machine

B Plain gages, inside dimensions
1 Calibrated size blocks
2 Micrometer and taper wedges as shown in Fig. 2 for snap gages
3 Calibrated size blocks for snap gages and ring gages
4 Special device, using mechanical indicator, for ring gages
6 Use of thread plug check gages for determining effective diameter of ring thread gages.

Throughout all phases of the measuring work, apparatus and instruments are carefully calibrated against precision standards, which have been verified by the light-wave interference method in the Optical Laboratory of the Bureau of Standards. As far as possible measuring instruments are used as comparators, thus eliminating errors which might arise due to imperfection in measuring instruments.

Descriptions, drawings, and other information with reference to the design and construction of gage apparatus previously listed, may be secured from the Bureau without charge, and demonstrations of different pieces of apparatus and methods of test can best be realized by visiting one of the gage laboratories.

Fig. 1 Gage Laboratory, Bureau of Standards, Washington, D. C.

5 Inside micrometer, used as comparator only
6 Special forms of star gages
7 Use of standardized steel balls, size blocks and taper wedges

C Profile gages
1 Gaertner measuring machine
2 Projection lantern
3 Surface plate set-ups, employing sine bar, size blocks, mechanical indicators, calibrated steel balls, wires, plugs, etc.
4 Special applications for surface plate work of micrometer microscope.

D Thread gages
1 Special lead-testing machine for measuring pitch or lead of plug and ring thread gages
2 Projection lantern for examining form and angle of plug and ring thread gages
3 Calibrated micrometers and wires for measuring effective diameters by 3-wire method
4 Calibrated micrometer calipers and bench micrometers for plain diameters of thread gages
5 Three-ball method for measuring effective diameter of ring thread gages

Research and Experimental Work

Until recently the energy of the Gage Section has been devoted mainly to the test and certification of gages. However, in this work there has been accumulated a vast amount of information and data on the construction, measurement, and use of all kinds of gages, and it is planned to use the technical staff now available for the preparation of pamphlets, publications, and other literature in order to make this information accessible to American manufacturers. In addition, there are a great many problems upon which research and experimental work should result in improvement in the manufacture and use of tools and gages. Among the problems which are under investigation at the present time will be mentioned the following:

1 Experiments to determine the proper thread allowances and tolerances for wrench fits in cast-iron, aluminum and other materials
2 Compilation of formulae and description of methods of test of complicated profile gages and thread gages
3 Compilation of designs of gages found to be most practical for different classes of work
4 Investigation of the cutting properties of taps to determine the amount the tap cuts over-size when new

and when worn under different conditions of lubrication and with different materials

5 Investigation of suitable steels and their heat treatment, to determine the most suitable steel for a given type of gage

6 Life of different types of gages.

Fig. 2 Method Used in Testing Snap Gages

Gage Shop

The Bureau of Standards in Washington has, in addition to the Gage Laboratory, a shop which includes about 75 machine tools. This shop has been of great utility in the salvage of master gages purchased by the Ordnance Department and Motor Transport Corps and for the manufacture of gages needed in cases of exigency to prevent stoppage of production or to facilitate the shipment of munitions over-seas, which was being held up owing to lack of final inspection gages. The equipment of this shop is such as to permit the manufacture of practically any type of gage required for the manufacture of ordnance, aircraft, and motor trucks.

One of the important phases of the shop work was the development of a process of manufacturing precision gage blocks similar to the Swedish or Johansson gage blocks, described in Mechanical Engineering for March, page 289, and for May, page 484. The manufacture of these blocks was undertaken about September 1, 1918. These gages are being produced to within an accuracy of five millionths of an inch for flatness and parallelism of faces and of absolute length.

It is not surprising that in some cases there has been a misunderstanding among manufacturers regarding the purpose and utility of the gage work at the Bureau of Standards. There have been instances where a manufacturer, not knowing the facts, has been under the impression that the chief cause of his rejected gages was the extremely close specifications and tolerances originated by the Bureau. There are other cases where manufacturers have imagined that the inspection methods of the Bureau were purely theoretical and, furthermore, that the chief aim of the Bureau was to find errors in gages by a minute examination with apparatus and devices suited only to the needs of precise scientific work.

The function of the Gage Section of the Bureau, during recent military preparations, has been to examine gages purchased by the War and Navy Departments and determine from a disinterested standpoint whether or not these gages corresponded to the specifications and tolerances laid down by the department for which the gages were purchased.

The Bureau of Standards is a government institution organized under the Department of Commerce for the development, construction, maintenance, custody, and use of standards of measurement, performance, and practice. It is by necessity a scientific institution and its relation to various branches of the federal government, to manufacturers and individuals, can be nothing but absolutely impartial. The policy of the Bureau is to extend to manufacturers every opportunity to secure information resulting from experimental and routine activities. In placing at the disposal of manufacturers the designs of apparatus, descriptions of methods of test and by demonstrating to gage manufacturers the advantages of better measuring facilities, many manufacturers have been able to improve their product and have realized the purpose and facilities available at the gage laboratories of the Bureau. During the war, courses of instruction were offered to gage makers and gage inspectors in the employ of the government or manufacturers having government contracts, and in this way further benefit and coöperation was secured.

Future Work

The results to be accomplished and the service to be rendered to American manufacturers during the reconstruction period will depend largely upon the demands made by manufacturers upon the facilities now available. The inspection laboratories at Washington, Cleveland, and New York can accommodate an appreciable amount of gage testing work and, in addition, can be used to good advantage for the demonstration of measuring apparatus, methods of test and for distributing technical information on gage problems. For routine work of the certification of gages, where the tests are of benefit to but one or two parties, a nominal fee is charged for the work done. However, where investigations and research are carried on, and where the results are of general utility to American manufacturers, no fee or charge is made for the resulting information or service rendered.

In the reconstruction of our industries, if we are to compete with foreign countries and not only share but lead in manufacturing progress, it will be necessary to secure a better quality of product at a minimum of cost, and in this problem the combined results of scientific, engineering, industrial, and commercial endeavor towards standardization is most essential. With this thought in mind, the facilities of the gage laboratories of the Bureau of Standards are available to American manufacturers.

The particulars of the thread-cutting mechanism of an engine lathe now manufactured by Brödrene Sundt, Christiania, Norway, are given in an article in the September issue of *Machinery*. The lathe is equipped with two lead-screws for cutting both inch and metric screw threads, and the gearing is so arranged that coarse threads, or helical grooves with leads up to 12 inches, may be cut, in addition to the usual range of pitches for threads. The headstock is so designed that its gear ratios may be utilized in connection with screw cutting. With this arrangement, the number of pitches ordinarily attained will be multiplied by the number of gear ratios in the headstock. There is one lead-screw for the inch pitches and one for the millimeter pitches. The metric lead-screw is practically a threaded feed-rod. By means of an additional screw on the feed-rod, metric threads can be cut without using translating gears and by employing the same gearing as for the inch pitches. The inch lead-screw is $\frac{1}{4}$ inch pitch, and the feed-rod 4 millimeters pitch; hence, when the lathe is geared for cutting 1/16-inch pitch, it is also geared for cutting a pitch of 1 millimeter with the metric lead-screw. The change-gear box in connection with one set of spur gears and the gear ratios of the headstock provide for cutting 342 different pitches: 167 inch pitches and 175 millimeter pitches. These different pitches are obtained by shifting handles or levers.

Gage Limits in Interchangeable Manufacture

By E. C. Peck,[1] Cleveland, Ohio

As indicated by the title, it is the purpose of the following paper to present modern gage practice as applied to interchangeable manufacture. As an introduction the author first discusses the merits of the English and metric systems, and suggests that a 10-in. meter would be a most desirable unit. Some interesting facts in the development of interchangeable manufacturing methods are next presented. The author also gives an explanation of the terms allowance and tolerance, and the method of using gages in strict interchangeable quantity production are outlined in some detail. The paper concludes with a discussion of the methods of interchangeable screw-thread manufacture.

The word gage is the name which has been given to a large number of instruments and appliances used in determining dimensions, capacities, quantities, forces, etc. Gages have been used since man first began to contrive conveniences for himself. The standards of weight, measure, and volume mentioned in the Bible are simply gages, and the instruments and appliances used in building the pyramids can be likewise so considered. In fact, it has been apparent from the beginning of time that standards for determining dimensions, capacities, quantities, forces, etc., are absolutely necessary in conducting all kinds of commerce and business.

In early times many tribes, states, and countries used gages originating with themselves, and in all probability the tribe or state which did the most trading succeeded in establishing their standards in other countries, and it is these standards that have been handed down to us. It would, however, have been much better for the present generation if there had been more coöperation among the ancients in regard to standardization, for then we would not have had our present heterogeneous collection of gages or units.

At the present time there is a consistent effort towards the establishment of international standards and there is no doubt but that the near future will see rapid strides in that direction. The World War has done more to help this movement than all the propaganda of the last decade, for it has shown in a very practical way the delay, trouble, and cost of production when a number of different standards are in use.

It would seem like a logical statement to say that some one system of standards ought to possess sufficient merits to win over the entire world by its greater utility, but this has not proved to be true. First, we have the natural pride of every country against giving up its own standard for that of another, and second, the objection of the industries themselves because of the cost involved in the necessary purchase of new gages and tools.

English vs. Metric System

The two systems which most concern this country are the English and metric. Both are used extensively, both are legal and both have warm advocates. It is obvious that the outstanding advantages of the metric system have not been sufficient to supplant the English in this country. Doubtless the chief advantage of the metric system is that all subdivisions are multiples of ten, and hence in calculation it is only necessary to move the decimal point in the reduction from unit to unit. Great advantage is also claimed in that the units of weight and volume are derived from the unit of measure, but to the writer this is of little account because for accurate work one does not want to originate his own standards but prefers to obtain them from a recognized bureau of standards.

One advantage claimed for the English system is that most sub-divisions are made by successively halving each unit. If these arguments are adhered to by the advocates of each side they both fail, because their methods result in units whose sizes are impracticable as has been found by experience.

In the English system, beginning with the inch and halving for each subdivision, we finally reach the units 1/64, 1/128, 1/256, 1/512, and 1/1024, all of which are awkward to handle and not readable on the well known micrometer without estimating. To obviate this difficulty, the inch is divided into tenths, hundredths, thousandths, and ten-thousandths, and all of these decimal units are practicable and usable units.

In the metric system the first subdivision of the meter is the decimeter, a unit 3.937 in. long, of no utility and rarely used. The next unit is the centimeter, a unit too large for good work and too small for use in distance measurements.

The next is the millimeter, 0.03937 in., the most widely used unit because of the adaptability of its size value. Many industrial enterprises require no greater accuracy than a millimeter, and, therefore, as this unit is about as fine as can be used on a steel scale it is sufficient for their needs.

For tools and fine accurate mechanisms the millimeter is too large, and so is the next subdivision, 1/10 millimeter, which is 0.0039 in. The great bulk of good work in our machine tool, automobile, and the tool making industries require units between 1/10 and the 1/100 millimeter, as one is too coarse, and the other too fine. Because of such fact there has resulted a halving and quartering of the millimeter and the 1/10 millimeter to obtain usable units approximating 1/100, 1/000 and 2/1000 of an inch. Thus it will be seen that the advocates of both systems use what the other claims as an inherent fundamental of his favorite system, and this, of course, proves the utility of it.

The impracticable size of the units of the metric system is, in the writer's judgment, the greatest stumbling block to its universal adoption, and if when the meter was adopted, all romance and sentiment had been left out of the question, and the meter made 10 English inches long, then the metric system would have been in universal use long ago.

If the meter were 10 English inches long, a decimeter would be the well-known standard inch, and the other decimal subdivisions the familiar decimals of an inch, all of which are thoroughly practical working units. The present 10-foot pole which is extensively used, would be 12 meters long, and 4 meters would easily have been substituted for the yard, as the error is only 1½ per cent. Furthermore 2 dekameters is within 2 inches of the English rod and as a unit would be satisfactory. The mile would be 6336 meters, just as easy to handle as 5280 feet.

The adoption of the 10-inch meter would have simplified at once the adoption of an International Standard Thread System, for the metric threads could have been expressed in whole numbers per decimeter, and this would not only agree with present practice, but would also fit in with the United States system.

Interchangeable Manufacture

The first interchangeable manufacture attempted was in France in the year 1717, and although it failed, another trial was made in 1785. This, however, also failed. In 1798 Eli Whitney of cotton-gin fame took and completed a contract to make ten thousand muskets for the United States Government. The parts of these guns were to be interchangeable.

English and French ordnance officers ridiculed and criticised Whitney's ideas to such an extent that Congress became alarmed and so Whitney went to Washington with ten guns and after distributing the parts on the floor assembled repeatedly from these parts ten guns that operated properly. This remarkable

[1] General Supt., Cleveland Twist Drill Co., formerly Lieut.-Col., Ordnance Dept., U. S. A. Mem.Am.Soc.M.E.

Abstract of a paper presented at a meeting of the Washington Section of The American Society of Mechanical Engineers, April 30, 1919.

achievement astonished everyone and it is believed to be the first successful interchangeable manufacture of accurate work. As nearly as can be determined from records available this occurred in 1800. In 1808 Simeon North accomplished a like feat on pistols for the Government and it is claimed by some that he was the first to introduce interchangeable manufacture.

While it is a matter of record that John George Bodmer began to manufacture guns at St. Blaise in the Black Forest about 1806 by a method which is believed to have been partly interchangeable, such methods of manufacture are conceded to be an American development, and are described by writers on the continent as an American method. In 1853 a British commission visited the United States to investigate the methods in use, and as a result ordered 20,000 Enfield rifles for the British Government, and later 157 machines for the Government arsenals. They also hired James H. Burton to install the machinery and methods.

From this small beginning the practice grew steadily in the armories and arsenals, and later, as the advantages became known, it spread to bicycles, typewriters, and various other articles, until now it is quite common to speak of interchangeable manufacture. There is no doubt, however, but there is some difference between the exact meaning of the term as used then and at present, just as there is also a great difference between manufacture at that time and the present.

There are several degrees of interchangeability, or at least several meanings to the exact interpretation of the term. Strict interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part will fit and properly function in any one of the whole number of mechanisms, no matter when or where it is made. It will be noted that this definition means that each part of the mechanism of a certain model will fit any of the mechanisms of the same model regardless of the lot to which it belongs or the year in which it was made. Some interchangeability consists in making each part fit any mechanism in a certain series, that is, the interchangeability exists only in the same series.

In the early days, before modern machinery came into use, it was necessary to finish work by hand, and to make it uniform, template filing and finishing was employed. For example, gun and pistol parts would have the holes drilled and reamed in a jig or fixture, and then the contour finishing done by putting these pieces into a template jig provided with pins to fit the holes. The outside of the jigs would be a duplicate of the shape and size of the model piece but hardened. The workman would then file down to the hardened template, which controlled the shape and size of the piece. Many ingenious devices and schemes were used to facilitate the duplication of parts, and great skill was developed by the workmen.

The great improvement in machine tools, especially as to accuracy of output, has been a very large factor in promoting interchangeability, and here again America has led the world. The refinements, accuracy, and efficiency of modern machine tools are strictly American, and are the outcome of the demands placed upon them by interchangeable manufacture at a low cost.

American labor costs so much more than foreign that to compete in the world markets we have been forced to obtain as much product for each dollar of labor as our competitors, and we therefore have been compelled to develop machinery to get more product for less labor. This, in turn, has developed skill in our mechanics and raised the standard of living of the American skilled workmen.

Allowances and Tolerances

It is a fundamental law that interchangeable manufacture is facilitated by the largest allowable freedom in the fit of mating parts without interfering with the proper functioning. This statement leads to the subject of allowances and tolerances, one of the simplest but least understood in the whole system of interchangeability. As these two words will be used repeatedly, it is well to point out the difference between them.

Allowance is a prescribed difference between the dimensions of two mating parts to produce a desired kind of fit. For example; a standard hole exactly 1 in. in diameter, contains a free running shaft, the journal diameter of which is 0.998 in. The difference between this hole and the journal prescribed for the oil film is 0.002 in., and this is the allowance.

Tolerance is the prescribed difference in the dimensions to tolerate the unavoidable errors or variations in manufacturing a large number of pieces. In the example just given, if a thousand running fits were to be made, the holes might be dimensioned $1.000 \text{ in. } {}^{+0.0005}_{-0.0000}$. This half thousandth permissible error is the tolerance. The shaft journal might be dimensioned 0.997 to 0.998 in., and this permissible error of 0.001 in. is the tolerance. Then the minimum allowance is 0.002 in. and the maximum looseness, or the sum of both tolerance and the minimum allowance, is 0.0035 in.

Thus the kind of fit is finally determined by the combination of the allowance and tolerance, and most engineers prefer to use allowance as a minimum value, which is never intentionally encroached upon, the tolerance providing for larger freedom of fits. The reason for this is that the data for minimum allowance are more reliable and has been more clearly demonstrated than the maximum allowance, and as it is vital it must be uneffected by tolerances. This is plainly evident in the case of free moving parts, as it is well understood that a space must be provided for an oil film, and this space must not be so small as to endanger failure by the parts seizing. Again, it has rarely been determined, except in individual cases, how loose moving parts can be before they are unsuitable. It must also be understood that the tendency of the engineer is in the direction of longer wearing life of the parts, hence the tendency to decrease maximum allowance or looseness.

There are many conditions in which maximum looseness determines the strength of the parts or the limits of engagement, and any more freedom of fit would make the parts unsatisfactory. When this is the case, maximum looseness must be the starting-point in the calculations, and must then be uneffected by tolerance. Then if minimum allowance can be determined, the difference between these two (maximum and minimum looseness) is the sum of the tolerances.

The tolerances are then divided between the mating parts according to the manufacturing ability to produce the parts to uniform size. That is, if the manufacturing ability is such that it is much easier to produce one member, to a uniform size, than another, the tolerance on the members is divided in direct proportion to this condition. When the dimensioning is finished, we will have the equation—maximum looseness equals minimum allowance plus the sum of the tolerance of both parts, and this equation will apply whatever the known factors are.

Very often the allowance has zero value, that is, there is no clearance whatever allowed for the fit, and in a single pair of mating parts they fit metal to metal. If a large number of such parts are to be made it must be determined whether this zero allowance is for the tightest or the loosest fit permissible, and then substitute the known values in the equation just mentioned.

The term "negative allowance" is often used to indicate that a certain prescribed amount is allowed so as to make a tight or force fit. This is very confusing because it implies being subtracted, whereas such is not the case. According to present usage, zero allowance indicates that there is no clearance or space allowed between the two mating parts. Positive allowance indicates that there is prescribed a space between the mating parts. Negative allowance indicates that there is less than a space provided for between the mating parts, or an imaginary space displaced by the flow of the metal to make a tight fit. Negative allowance should, therefore, be treated as a negative quantity in the formula above mentioned, and then the quantity resulting used for either greater or less looseness, according to whether the sign of the quantity is positive or negative.

The minimum allowance, or greatest tightness and maximum looseness, must be known when the tolerances have been set, and usually they are known at such time. There are, however, cases in which it is known that certain tolerances are the smallest that can be successfully used in manufacture, and then maximum

looseness and tightness must be adjusted to obtain the best functioning condition in conjunction with these tolerances. This occurs often in very close work.

After determining the maximum and minimum looseness of mating parts and setting the tolerances it becomes necessary to control the dimensions of the parts so that none of the dimensions will be outside of the limits established, and this is best done at this time for strictly interchangeable manufacture by the use of proper "go" and "no-go" gages. First-class gages are expensive and soon wear, so that strict interchangeability is sacrificed to keep down gage cost.

Past Methods of Using Gages

In times past it was common practice to use only "go" gages and limit the looseness of fit by the shake of the piece in the gage, or, where a little more refinement was practiced, a piece of newspaper was used on one side of the "go" gage, and if the piece which passed without the paper was tight with the paper it was accepted. A piece of newspaper used with each of a pair of mating "go" gages usually produced a freedom of fit of from 0.004 to 0.006 in., and with skilled help it produced satisfactory results.

For a strict interchangeable quantity production work of good character, a good gaging system will prove economical. Such a system comprises the minimum number of properly designed gages to control all the factors of the various parts of a mechanism so that they will assemble and function properly. As stated before, this assumes that proper allowances and tolerances have been established.

The designer should always remember that tolerances should be as large as proper functioning will permit, and he should be well informed as to what tolerances successful manufacturers actually work. He should take pains to inform himself how tight and how loose working parts can actually be and give satisfactory results.

Once these tolerances are set as large as the designer will risk, they should be rigidly adhered to, and considered a boundary line. The product should always be kept within these boundary lines, and this is best accomplished by making the component drawing dimensions the master gage dimensions. Then with all the working and inspection gages checked against the master gage, and never allowed to wear beyond master gage dimensions, the work is bound to be within component dimensions.

The procedure just outlined gives us the definition of master gage, namely; they are for reference only, and represent the extreme tolerance limits allowed on the parts being made. They are often the same design as inspection and working gages. In many cases, however, they are in the form of checks or master component parts for the purpose of checking the actual inspection or working gages. In all cases the dimensions are the exact physical standards and represent extremes of the component dimensions.

As exact duplicate master gages cannot be made except at a prohibitive cost, a master gage manufacturing tolerance is allowed. This tolerance is usually in good practice from 4 to 6 per cent of the component tolerance, and is applied in the direction to keep the work within the boundary line defined by component dimensions. This gage tolerance is treated as a wear limit, and robs the working tolerance by this 4 or 5 per cent.

Inspection gages are usually of the same design as the working gages, and often the same as the master gages, but they should have an additional allowance for wear. Inasmuch as the gages will wear, and as they are expensive, the exact amount to allow for wear is an economic point for each manufacturer to decide, keeping in mind that a small wear limit increases the gage cost, and a large wear limit requires closer attention and work at the machines.

Where experience is lacking, it is good practice to allow 10 per cent of the component tolerance for wear on the "go" gages, as the "no-go" gages wear but little, 5 per cent will be sufficient. The inspection gage can only represent extreme tolerance limits when worn to master gage size. The working gages are those used to check the work as it is machined, and should have liberal wear limits to insure the work being passed by the inspection gages.

Thus it will be seen that this system, if followed, will admit of the acceptance of work that will be interchangeable. It also emphasizes the fundamental that tolerance should be as large as will properly function, for if the tolerances are too small the work will be more costly, as better workmen will be required, and this always means higher wages. Better tools and machines to produce the close work, and more frequent adjustment and attention will be necessary also, and this will likewise increase costs.

Screw Thread Work

The examples and descriptions thus far given have applied to all kinds of interchangeable work, with no particular reference to screw thread work; and, while the principles and practice are the same, a great deal more care is required to produce strictly interchangeable screw thread work than plain work. The problem becomes more difficult because a larger number of factors make up a proper screw thread fit, and a large error in any one of them will prevent a proper fit. A comparison of these factors may help to make the solution more comprehensible. A cylindrical fit depends upon the size, rotundity, and parallelism of the mating parts. Rectangular and sliding fits depend upon size, contour, rotundity, and parallelism of the mating parts, and to a considerable extent upon the ability of the metal to flow under stress. Of course, all depend upon size, but in a screw thread fit size is effected by the errors of the lead in the mating parts and the errors in the angle of the thread. Thus the factor contour in a screw thread is made up of the factors of lead and form of thread.

Two mating parts with correct lead require no compensation in size for the lead factor. Two mating parts with an equal lead error in the same direction, either long or short, require no compensation in size for the lead error. Two mating parts with differing lead errors, or the equivalent, require a compensation in size for this lead difference to enable the mating parts to go together.

Two mating parts in which the contour of the thread is effected by having an error in the angle of the flanks of the thread must also have a compensation in the diameter to offset the angle error, or the metal must flow to make the fit. Thus it will be seen that strict interchangeable screw thread product is more difficult to produce than plain work, and if good fits are required close tolerances and good thread producing tools are necessary. There must also be a rigid inspection, and means of controlling all the factors which make a fit.

Where gages are used, as at the present time, they must be periodically checked against the master gages in order that boundary lines are not encroached upon. It is fundamental that the "go" gages should check all the factors simultaneously, and the "no-go" gages should check the factors separately. This must be obvious when it is remembered that lead and form errors are compensated for by increasing the diameter, and hence to be sure of the correct relation of all the factors to each other they must be gaged at once, and with a gage as long as the engagement of the mating parts. The exception to this is the minor diameter of the nut and the major diameter of the screw. To include these two dimension factors in the "go" gages would make the cost of the gages prohibitive, and as these surfaces in the mating are intended to be cleared when assembled, it is practicable to gage them separately.

There has been considerable said about robbing the tolerances with the gages, especially where the fits are close and the tolerances small. As a matter of fact, if the master gages are exactly to the component dimensions they do not rob the tolerance at all. This can be demonstrated by gaging the mating parts of threaded work with a plug and ring thread gage which are correct form, lead, and diameter. If these gages fit snugly, requiring some hand pressure to screw them together, the work which they gage will go together at least as freely as the gages do, even if the lead is correct, or if there are errors in the opposite direction.

(*Concluded on page 858*)

Refrigeration Requirements of Chemical Warfare

By MAJOR A. M. HERITAGE,[1] U. S. A.

Had the war continued, chemical warfare would have unquestionably assumed greater and greater importance, and even as it was it is common knowledge that the use of gases had no small part in the conduct of the war. The problems associated with the production of gases and gas-filled shells involved the creation of many plants and the undertaking of tremendous tasks. Such duties naturally fell to the lot of the chemist and engineer, and upon the mechanical engineer in particular, devolved the design and operation of the necessary refrigerating systems used in connection with chemical warfare. It is the purpose of this paper, as its title indicates, to discuss such a use of refrigeration, and the author first describes the properties and manufacture of many of the gases which were in general use during the war. He next outlines the method of manufacturing phosgene filled shells, and in conclusion discusses the need and uses of refrigeration and the type of equipment usually employed.

WHEN, on April 17, 1917, the United States Government declared war upon the Imperial German Government it became apparent that it would be necessary to fight the enemy with its own style of weapon. The Huns had been using gas in various forms since April 22, 1915, to fight the British and French, and commercial concerns in our country had engaged somewhat in furnishing the Allies with certain materials used to make toxic gas for filling shells. Up to this time, however, our Government had not engaged in the manufacture of toxic gases, and it, therefore, became necessary not only to immediately investigate and stimulate the manufacture of poison gases but also to devise a process for placing these gases into projectiles.

The initial step was taken by the Government on April 6, 1917, when a sub-committee of the National Research Council met and plans were made for extensive research in all matters pertaining to toxic gases. This sub-committee, under the chairmanship of the Director of The Bureau of Mines, was composed of representatives of the Army and Navy, and civilian chemists, gas experts and physiologists.

This enormous task, to be thus undertaken, was assigned to the Trench Warfare Section, Gun Division, of the Ordnance Department, and out of this small group of men grew a new corps known as the Chemical Warfare Service of the U. S. A. The Chemical Warfare Service, A. E. F. was formed independent of the Chemical Warfare Service, U. S. A.

Since no plan whatever was provided for chemical warfare when that service was organized in France, the Commander-in-Chief wisely permitted a wide latitude in its formation. Thus it was that the Chemical Warfare Service in France, as well as that organization nine months later in the United States, included research, development, production and supply, training in gas defense, chemical warfare intelligence, and the actual training, equipping, and operating of gas troops. These latter, of course, were handled in battle by the Chemical Warfare Service entirely in accord with and under orders of the commanding general of the armies, corps, and divisions with which they were operating.

This was a very fortunate organization. It permitted the widest latitude in using the personnel obtained to the best advantage, and in realizing very early the gas and gas defense needs of all other troops at the front. In fact, with its special knowledge of gases and gas warfare, the Chemical Warfare Service was enabled, in nearly every case, to realize the needs of the man at the front long before he realized them himself. It is believed that this is the soundest kind of organization, for the reason that it binds, into intimate contact, research, supply, experiment, intelligence, development, and actual fighting. The Chemical Warfare Service as organized in France had five subdivisions—Offense, Defense, Technical, Supply, and Intelligence. Experience indicated that Offense and Defense should be merged and that Training should be separate. These changes and other minor ones to adapt the organization to the regular General Staff organization appears to be the ideal, and was what the Chemical Warfare Service was working toward when the war closed.[1]

The gases experimented upon and used, some to a greater extent than others, were chlorpicrin, stannic chloride, phosgene, dichlorethyl sulphide (mustard gas), cyanogen chloride, chlorine, diphosgene, bromacetone, ethyl-iodoacetate, brombenzylcyanide, and diphenylchlorarsine. Of these gases phosgene requires the most refrigeration and the engineering problems solved in its manufacture were by far the greatest. Mustard oil also requires refrigeration in its manufacture but not during the process of the placing of the liquid into the projectiles.

The Properties and Manufacture of the Gases

A few words concerning the manufacture of the gases requiring refrigeration, although somewhat extraneous to the subject at hand, might nevertheless, prove of interest and for that purpose the writer quotes below from two recent articles, one by General A. A. Fries which was published in the *National Service Magazine* for June 1919, and the other by Major D. Domerest which appeared in *The Ohio State Engineer* for May 1919.

Chlorpicrin is a liquid boiling at about 115 deg. cent. and is made by reaction between bleaching powder and the high explosive picric acid. Picric acid is made by mixing phenol and sulphuric acid in sulphonators and allowing the mixture to age. This phenolsulphonic acid is added to nitric acid and water in nitrating pots, thus making picric acid. The spent acid is drawn off and the dry is mixed with water and calcium chloride, or lime, forming calcium picrate, and this is poured into a mechanical mixer together with calcium hypochloride, or bleach which has been creamed with water. The mixture is then pumped into stills where steam is introduced, as the reaction between the acid and bleach distills over into a water cooled condenser and the result is Cl_3NO_2, commonly called chlorpicrin which, being heavy, settles to the bottom and this allows any water carried over with it to be drawn off at the top.

Chlorpicrin was manufactured both at Edgewood Arsenal, Stamford, Conn., from which place there was shipped 111,853 lbs., and at Edgewood Arsenal, Edgewood, Md. This latter plant had an estimated capacity, January 1, 1919, of 3,000,000 lb. per month. This gas is highly lethal with low persistency and of it 3,806,000 lb. were shipped overseas.

Stannic chloride is a chemical made by passing chlorine gas over old tin cans. This gas when liberated in the presence of air produces a dense, white smoke cloud. It is also known as chloride of tin, and when added with chlorpicrin in gas shells, proved to be an excellent marker for the gunner.

Cyanogen-chloride, chlorine, diphosgene, and others of a similar nature are also highly lethal gases with low persistency. Bromacetone, ethyl-iodacetate, brombenzylcyanide, diphenylchlorarsine, or sneezing gas, and several other lachrymators are all highly irritating but not lethal except in extremely high concentrations. Lachrymators are highly economical in forcing the wearing of the gas masks and are used principally for that purpose.

Mustard gas, called yperite by the French, is the king of all gases. It is estimated that more than 80 per cent of all gas casualties among the English and Americans was caused by this gas. Technically it is dichlorethyl sulphide. This gas was discovered by a German chemist, Victor Mayer, in 1886. He pursued his experiments until he saw that the gas was having as serious an effect upon his experimenters as upon the animals experimented with. At that stage he stopped.

It is interesting to note that an English chemist recommended the use of this gas a year before the Germans began using it. But

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[1] Chemical Warfare Service, Edgewood Arsenal, Baltimore, Md. Assoc.-Mem. Am. Soc. M. E.

The author desires to give credit to the American Society of Refrigerating Engineers for permission to publish the latter part of this paper, which was presented before the Sixth Western Meeting of that Society at Cincinnati, Ohio, during May 1919, and which appeared in their Journal of the same month.

[1] These two paragraphs are quoted from an article by General A. A. Fries which appeared in the *National Service Magazine* for June, 1919.

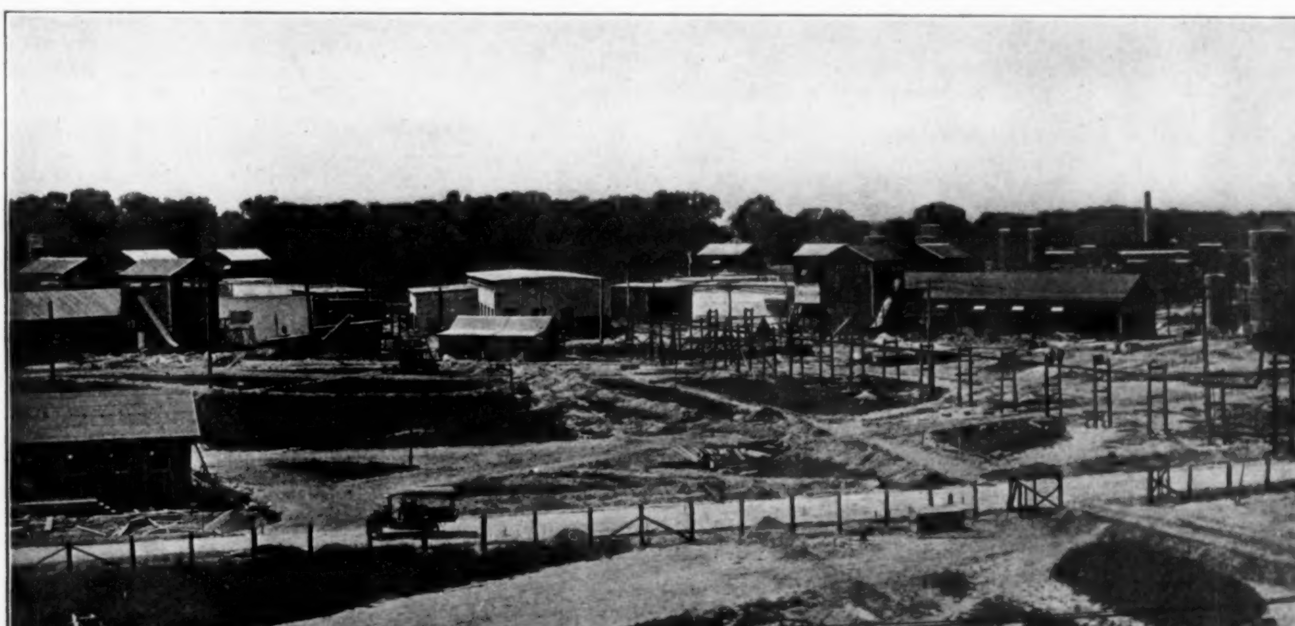
here, as in the case of many other things, there was either too much fear, or hostility, or perhaps both, to new ideas, and once again the initiative was left to the Germans.

The gas is a yellowish oily fluid, freezing at about 50 deg. fahr. and boiling at about 422 deg. fahr. and its color varies with the impurities and solvents in it. It appears to combine to a certain extent with the iron or steel in shells, because the mustard gas as seen sprayed on vegetation from bursting shells appears to vary from fairly dark brown to almost tar black. The modern method of making it is to agitate sulphur-monochloride vigorously in the presence of ethylene vapor.

The gas is highly persistent—that sprayed on the ground being dangerous from a minimum of about two days in warm dry weather to a week or even longer in damp cold weather. It vaporizes very slowly. The idea will naturally occur that it must be effective in extremely low concentration or else its slow vaporization would make it useless, and that idea is correct. It is claimed that the highest concentration of the gas that can be obtained at 65 deg. fahr., is about one part in 30,000 of air. It has, moreover, the quality of cumulative effect to a very marked degree, being fully 50 per cent even for very low concentrations. For example; one part in 2,000,000, if breathed for 20 hr., will produce as serious a casualty as one part in 100,000 will produce in two hours; that is, if you multiply the time by 10 the concentration can be decreased to one-fifth and yet get the same result.

Mustard gas produces casualties almost wholly by burning. The theory is that the gas in the presence of moisture is broken up so as to liberate hydrochloric acid and that this acid produces the burn. The gas accordingly burns any soft moist tissue it reaches, whether inside or outside the body. Moreover, as it readily penetrates clothing, all soft parts of the skin are burned by the true gas, which is contrary to the original idea that burns were caused only by splashes of the liquid. The mustard gas of the Germans has an odor somewhat like mustard and that of the Allies exactly like garlic. Finally the gas has a pronounced delayed action, as its effects are not felt until 4 to 12 hr. after exposure, during which time the person breathing it experiences no discomfort. It should also be added that after breathing the gas for from thirty minutes to two hours, depending upon the person, one loses his sense of smell and can no longer detect the gas. As may be readily imagined these qualities make it highly valuable, or highly dangerous, depending upon which way you are looking at it. Indeed, as before said, it is the king of gases. It

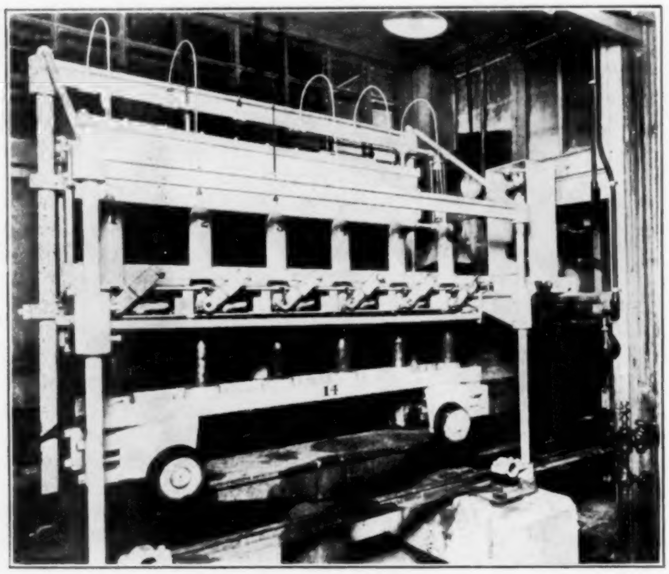
A General View of the Phosgene Manufacturing Plant



A General View of the Shell Filling Plant

changed not alone gas warfare, but to a considerable extent all warfare.

Mustard gas shells were picked up and opened after the first attack against the British in July, 1917. The English extracted the gas and within 48 hr. knew its composition. Within a week they had found, in German chemistries, Mayer's account of his discovery and the laboratory methods for making it. Notwithstanding an early realization of the importance of this gas and the determined efforts made to manufacture it on a large scale by the English, French, and Americans, it was almost eleven months after its first use by the Germans before the first Allied mustard gas attack took place. This was made by the French in the vicinity of Compiegne in June 1918. Thus for eleven months the German had a tremendous advantage over the Allies. That he did not make a greater use of it was surprising to the Allies until just before the armistice, when it was learned that he had been making it by a cumbersome, slow, and expensive method, and that his total production was only about six tons per day. It is interesting to note that before the armistice was signed the Americans actually made 40 tons in one day and were equipped to make 80 tons but had not the shell in which to put it.



Shell Filling Machine

Mustard is a liquid boiling at 219 deg. cent., which gives out vapors highly destructive to the mucous linings of the body, and the liquid itself is terribly destructive to all living flesh that it touches, producing fearful burns. It is made by passing ethylene gas into liquid sulfur chloride reacting according to the following quotations:

$$2C_2H_4 + S_2Cl = (C_2H_4)_2SCl_2 + S$$

This reaction looks very simple but is exceedingly difficult to carry out practically. Sulfur chloride is a liquid easily handled and easily stored and obtainable in large quantities. Ethylene is a gas which had to be made in a plant on the grounds erected for that purpose.

To make ethylene 95 per cent ethyl alcohol is vaporized by steam and the vapors passed through 8-in. tubes filled with kaolin in the form of sphagetti and heated from the outside to a temperature of 550 deg. cent. Under these conditions the alcohol decomposes thus:

$$C_2H_5OH + heat = C_2H_4 + H_2O$$

About 80 per cent of the alcohol is thus decomposed and in the best practice yield 97 per cent ethylene gas, the undecomposed alcohol being condensed and recovered. It was necessary here to calculate the amount of steam necessary to vaporize the alcohol, and the amount of water and condensing surface required to condense the undecomposed alcohol and water vapor, and also to design an alcohol still to distill and recover the alcohol passing through the ethylene furnaces undecomposed. It was likewise necessary to operate a water gas plant for furnishing gas to heat the ethylene furnaces.

The ethylene, after leaving the condenser, was passed through a large scrubbing tower to remove the last traces of alcohol and ether remaining in the gas, then it was passed through especially designed sulphuric acid towers, built of lead and quartz pebbles, by which the ethylene was thoroughly dried, since moisture in the ethylene caused endless troubles in the mustard reaction. The ethylene gas was then compressed in reciprocating compressors, the size and power of which had, of course, to be previously calculated. From the compressors the ethylene was blown in the form of fine bubbles through the sulphur chloride in the reaction vessel.

Several varieties of reaction vessels were used and it was very difficult to secure a design whereby the difficulties resulting from the precipitation of sulphur set free in the reaction might be avoided. It must be remembered that this sulphur was mixed with "mustard" and was fearfully toxic. The reaction between ethylene and sulphur chloride is exothermic and since the temperature in the reactor must not be allowed to go over 38 deg. cent. owing to the precipitation of sulphur and decomposition of "mustard" in contact with iron at a higher temperature it was necessary to design the reactor with a sufficient amount of lead coil inside to keep the temperature of the liquid below 38 deg. cent. This was difficult owing to the tendency of sulphur to settle on the cooling pipes and make the cooling inefficient, notwithstanding that ice-cold brine was used. If the reaction can be carried out sufficiently rapidly below 38 deg. cent., the process is practical and the sulphur does not precipitate but remains in collodial suspension.

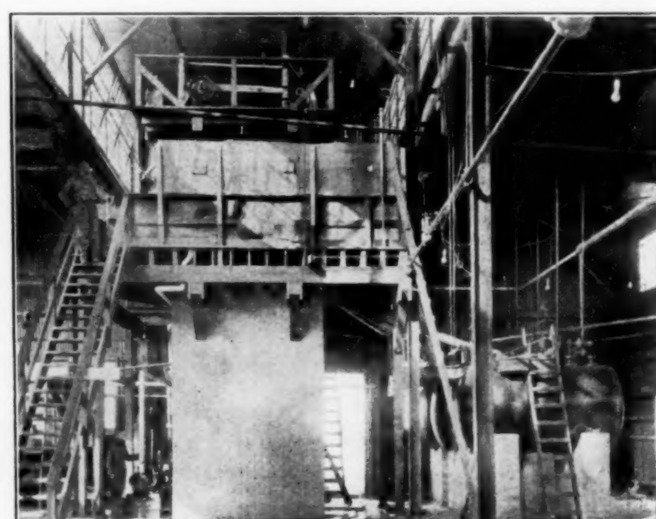
It was necessary to install blow cases for handling sulphur chloride and for pumping the "mustard" from the reaction vessel to storage tanks and from the storage tanks into drums for shipment across the seas or for transfer to the shell-filling plant. The chief difficulty at the "mustard plant," both in design and operation, arose from the necessity for taking care of occasional bad charges in which the sulphur precipitated badly and which resulted in stoppage of pipes. The most successful way to handle this difficulty was to dissolve out the sulphur mixed with "mustard" with an excess of sulphur chloride and pump the solution by means of a special pump built for pumping liquid sulphur through a steam jacketed pipe line into a large cistern in the swamp.

The day of the armistice the chemical plant was regularly and smoothly producing phosgene, chlorpicrin and mustard in quantities larger than shipping facilities could take it across the water and 1500 tons had accumulated stored in steel drums at the Chemical Plant.

Phosgene is a gas condensing at 8 deg. cent., and is made by a catlytic reaction between carbon monoxide and gaseous chlorine, extremely porous carbon being the catalyst. The product is $COCl_2$, and is extremely poisonous, consequently all pipes, valves, and fittings had to be extraordinarily tight. To make this substance it was of course necessary to handle large quantities of liquid chlorine, more in fact than was ever dreamed of before, and to gasify it and to transport the gas in pipes in such a way as to keep the liquid and gaseous chlorine under easy control. It was necessary to design and have built special tanks for the storage of liquid chlorine, vaporizers for vaporizing the chlorine and to install extra heavy pipe and special fittings to handle the liquid and gaseous chlorine. All this involved a good many calculations based on vapor pressure, latent heat of vaporization, and density of chlorine liquid and gas. The results were very satisfactory.

The production of reasonably pure carbon monoxide had never been a commercial process until this plant was built and after a great deal of thought on the subject it was finally decided that it would be necessary to make use of the two following reactions going on simultaneously:

$$2C + O_2 = 2CO + 58{,}000 \text{ calories}$$
$$C + CO_2 = 2CO - 39{,}000 \text{ calories}$$



Installation of a Mustard Oil Reactor

The first reaction could not be conveniently used alone on account of the enormous temperature produced by the reaction endangering the safety of the producer. The second reaction could not be conveniently used alone since it is endothermic and would soon smother the fire, requiring a frequently reversing procedure with resultant low purity of gas. Upon calculation it is found that when making

proper allowance for radiation heat-loss the above reactions when going on simultaneously should produce a state of fairly constant temperature when 30 cu. ft. of oxygen is used with 50 cu. ft. of carbon dioxide. It was expected that when using seventy-hour foundry coke as the source of carbon that a carbon monoxide gas of 98 per cent purity could be obtained.

The Manufacture of Phosgene Filled Shells

The preceding paragraphs give a general knowledge of the gases used and how manufactured and as phosgene is the principal gas requiring refrigeration, on account of its low vaporizing temperature, the writer will discuss at some length the subject of the handling of this gas, as it is placed in the various kinds of projectiles. It should first of all be stated that mustard oil and phosgene both require two tons of refrigeration for each ton of gas manufactured. This is due to the heat of reaction between the sulphur chloride and the ethylene gas.

Phosgene is made by bringing CO and Cl_2 together in equal volume in the presence of a catalytic agent where chemical reaction produces heat. This heat is partly counteracted by passing the mixed gases through a double-pipe water-cooler and the water used in steam boilers for general heating purposes. The mixed gases are then condensed in large spiral lead coils with a cold circulation of brine surrounding them. This phosgene, which condenses to a liquid at 40 deg. fahr. is then stored in either 300 lb. steel containers or in large steel drums of one-ton capacity made of ⅝-in. steel plate, the empty drum weighing approximately 1650 lb. These drums, before introducing the phosgene, are cooled to prevent the first phosgene entering the drum from again vaporizing and causing pressure, thereby preventing other liquid phosgene from running by gravity into the drum.

It might properly here be stated, that about 10 cc. of phosgene liberated in close proximity to a person, or 0.0003 gram taken into the lungs or even one part in 200 of air breathed for ten minutes, is sufficient to cause death. From this, one can easily see that in transferring the cold liquid phosgene from the phosgene condenser, or its supply tank, into the storage drums it is absolutely necessary to allow none to escape and this is best done by precooling the drums and preventing the first phosgene from gasifying upon entering the drum. These drums are tested to a pressure of 5,000 lb. per sq. in.

The next task requiring refrigeration is the transfer of the phosgene from the drums into the system for filling shells and other projectiles. This was accomplished by means of steel mixing bottles made of ¼-in. plate, welded, and containing floats for regulating levels and especially made distributing valves for the admission and eviction of the liquid "gas" in and out of the mixing bottles. Phosgene is sometimes mixed with either chloropicrin or stannic chloride. The mixed gas, while probably not more toxic or poisonous than phosgene alone, is harder for the gas mask to hold against than the phosgene alone. The latter mixture, phosgene and stannic chloride, is made for the purpose of showing the artillerymen the point of explosion of the gas shell. This is accomplished by the fact that stannic chloride, upon coming in contact with air, produces a white smoke.

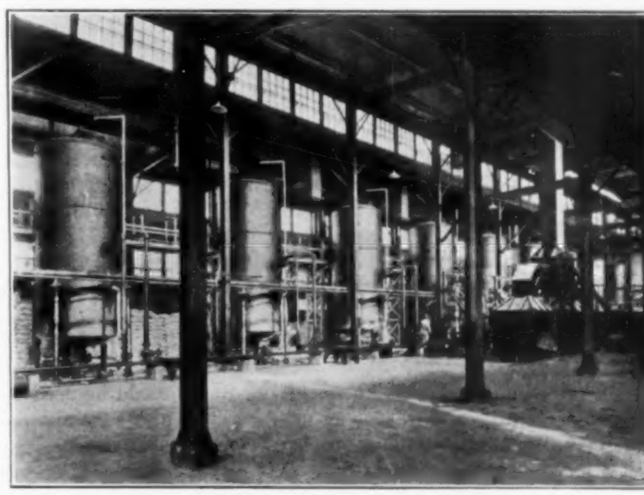
The Need and Use of Refrigeration

In order to fill shells or other projectiles with either straight phosgene or a mixture containing phosgene, it is necessary to cool the metal to a temperature below 32 deg. fahr, and as thousands of shells were filled per hour, and each shell weighed according to size from 10 to 90 lb., the amount of refrigeration required can be easily discerned. These shells and other projectiles, such as Stokes mortars and Livens projectors, were cooled by placing them on specially designed conveyors which traversed through rooms held at zero temperature. These rooms were designed with an anti-room at either end through which the conveyor carrying the shell travelled. The space necessitated by carrying three 75 mm. shell abreast on one conveyor, left open so far as cork insulation is concerned, was boxed in and hung full of felt strips which entirely covered and surrounded the shell and conveyor. The rooms were built with bunker lofts which contained, according to the size of the shell cooled, from 4,000 to 20,000 lineal feet of 2-in. direct expansion pipe and No. 5 ventura fans were used for circulating the heat given up by the metal of the shells over the direct expansion coils.

The program for filling gas shells at first being very uncertain on account of the lack of experience, it was decided not to build a too permanent an installation to start with and accordingly the buildings were designed for wood construction and mill shavings as an insulation. Accordingly, four buildings, 77 ft. long and 8 ft. wide with 15 ft. ceiling, were first built and a 3 ft. mill shaving insulation installed. This type of construction and insulation proved extremely satisfactory and the only change made in it was that a curtain wall of 8-in. hollow tile was set up on account of fire risk.

Recording thermometers were installed with connections leading from every room, which thus made the control very easy. The machines used for filling gas shells with phosgene were designed and worked out, using the siphon principle. These machines were all insulated as were all pipes containing the liquid "gases." The large containers of phosgene were taken from the rooms where they were filled and transported to the filling buildings on industrial railways. Here they were moved into small chapels—each one just large enough to place the container for connection to the shell filling system.

These chapels were kept under negative pressure, being connected to large ventilating scrubbing systems. The chapels were situated eight in a row, each one containing a chlorine pressure gauge and special gas connection. The fronts of the chapels were made with two vertically sliding glass doors and each chapel being under negative pressure, immediately as the door was raised, air was drawn in from around the attendant which prevented him from being gassed.



Installation for Production of Chlorpicrin.

Each chapel also contained a metal carriage made with ball-bearings and wheels which run on tracks set in the floor. These carriages were made with a revolving metal basket so that the large drum of phosgene could be placed in the basket and easily revolved for the purpose of bringing its outlet connection to the system's inlet connection. After a drum of phosgene was connected to the system, its pressure reading was taken to denote the presence or absence of ferric chloride and if satisfactory, it was allowed to run by gravity into a double pipe brine and gas cooler.

The brine used for circulation through these coolers was held at 15 deg. fahr. and the same brine was used for cooling the filling machines and the pipes carrying the gas from the double pipes of the brine and gas cooler to the filling machines. Experience taught many lessons and it was quickly discerned that it was necessary to have a drop leg in connection with the double pipe brine cooler for the purpose of collecting and removing ferric chloride, which precipitated out at low temperature. This ferric chloride is produced by water resulting from moisture in

the atmosphere coming in contact with the phosgene. It was also quickly learned that a large quantity of cold, dry air was necessary for the transferring of phosgene, for in this manner the liquid "gas" could be "shot" from one part of the system to another with little trouble.

Connections were made from the double pipe gas and brine cooler to the mixing bottles, which held 900 lb. of liquid "gas." Connections were also made whereby the liquid "gas" could be run from the mixing bottles back through the double pipe brine and gas cooler, thereby enabling the operator to mix cold phosgene with warm chlorpicrin and circulate the mixed gases back up through the double pipe brine cooler. The air used for the circulation of the liquid "gas" was produced by large air compressors run through dehumidifying systems. These systems proved very satisfactory although they required constant attention.

Each system was made of two banks of double pipes and a brine tank containing two sets of double pipes. The air coming from the compressors travelled through the double pipe air and brine color in the brine tank, which brine, in tank, was held at a temperature of 33 deg. fahr. From this cooler it traveled up through a double pipe brine and air-cooler above, which contained brine of a temperature of 15 deg. fahr. The brine cooler, located in the tank, had a pipe leading from the lowest air tube to a steam trap for the purpose of removing the humidity or moisture. The double pipe cooler above the brine tank was used for reducing the temperature of the air in the neighborhood which was approximately 32 deg. fahr. to -15 deg. fahr. Between the two sets of coolers, a large receiver was installed for the purpose of catching drops of moisture left in the air after passing through the first double pipe cooler.

Refrigeration Equipment

The machinery used was of the ammonia compression type and comprised various makes. Some were direct-connected engine driven and others were belt driven and used electric motors. The size of the machines varied from 12 tons to 120 tons refrigerating duty. Direct expansion piping was used entirely in the bunker lofts of the shell conveyor coolers and double pipe and shell type brine coolers used for the cooling and condensing of the phosgene.

All lead and steel pipes used for conveying the liquid "gas" were either burned or welded, or connected by means of flanged fittings welded on the pipes. No soldered joints could be used on account of the action of phosgene on tin. The phosgene showed little or no action on lead and on this account the phosgene condensers were made by wrapping 2-in. lead coils in special form around shell type brine coolers set vertically in large cylindrical steel tanks.

Several large installations at Edgewood, Md., due to a desire to keep the gas and ammonia lines short, were made by using a short belt drive with an idler. This short belt drive proved very successful and enabled the use of a narrow building. On either side of these ammonia compressor buildings were located the shell filling and phosgene cooling buildings,—two in number on each side. This lay-out made it possible for any one of four filling buildings or any one of four phosgene manufacturing buildings to be shut down, due to any cause such as bad gas leak, and the remainder left in operation without the operators being hindered in their duty. Inasmuch as each filling building and each phosgene gas manufacturing building required refrigeration which was produced at a central ammonia compression building, it became necessary to run liquid ammonia lines, cold brine lines, and cold dry air lines from the central buildings to each of these buildings. The idea of making the ammonia compressor buildings long and narrow made it possible for theses lines to be shorter than had long belt drives been used.

As stated before, the first unit of four shell filling buildings were insulated with three feet of mill shavings. The second unit of four shell filling buildings were insulated with sheet cork board set in plaster with a plastic cement on the outside for protection against the elements. The third unit of four buildings were insulated with sheet cork board plastered against an 8-in. hollow tile. The phosgene manufacturing unit of four buildings were insulated with sheet cork board and plastered. Various kinds of insulation were used for pipe covering and the kind which could be removed the more easily was the kind which seemed to be the most satisfactory,—especially on the cold phosgene pipes on account of speed being required to remove a pipe which developed a gas leak caused by the presence of ferric chloride. After removing many feet of covered pipe it was decided to build insulated box chambers around the cold pipes where they were located close together in connection with the gas mixing bottles. The double-pipe ammonia and brine coolers and double-pipe gas and brine coolers were placed in insulated rooms with cold storage doors which made them accessible for changes or quick removal.

In conclusion, one statement should also be made which is that the handling of phosgene gas in a liquid form readily collects moisture from any source, air included, and this causes the formation of ferric chloride. This ferric chloride denotes that iron is being given up from some source and that source, be it a cold pipe, is quickly getting thinner and this deterioration will quickly produce a leak because of the fact not only of the wall of the pipe getting thinner, but also of the fact that ferric chloride denotes the presence of hydrochloric acid vapor which produces great pressure. Tests made on samples of phosgene containing ferric chloride showed a pressure on a standard gauge up to 500 lb. This means that either lead pipe or extra heavy pipe with strong fittings and welded joints must be used. Of the hundreds of tons of phosgene made and filled into containers by the Chemical War Service, at its various plants, only three fatal casualties resulted and two of these were caused by the explosion of a phosgene container in one shell filling wing which caught on fire from some unknown source.

A new design for rigid airships which seems to eliminate most of the drawbacks of the existing types forms the subject of a recent British patent which has been taken out by a well-known firm of English motorboat and yacht builders.

In this design the hull of the airship is formed by a gas-tight shell made of several thin layers of wood veneer with layers of fabric between them, the whole being cemented and stitched together with fine copper wire, and internally stiffened by longitudinal and transverse girders. Such a monocoque hull offers several advantages over the conventional fabric-covered girder type for the following reasons:

First, owing to the fact that the shell acts at the same time as framework, outer cover and gas container, the monocoque design is for the same size or for the same weight lighter than the Zeppelin type.

Second, the veneer shell eliminates the tedious adjustment of the wire stays which brace the girder type athwartship and longitudinally, the transverse bracing being insured by veneer bulkheads which subdivide the gas container into compartments.

Third, head resistance is reduced to a minimum because no external projections beside fins and rudders occur on the hull, the machinery and accommodations being situated inside. The latter are separated from the gas container by a double wall, the space between which is filled with an inert gas, such as nitrogen, to reduce the fire risk when hydrogen is employed as a lifting gas. With the use of helium—which is non-inflammable—this double wall could most likely be done with entirely. The reduction of head resistance effected by such a design, where the airship is a strictly streamlined body, must obviously result in a considerable increase of speed for the same power.

Fourth, the monocoque hull promises to solve the much tangled problem of conserving the lifting gas for continued use, that is, without losing it through leakage or having it deteriorate by air penetrating the gas container owing to the imperfect gas tightness of existing balloon fabrics and their gradual deterioration due to sunlight. It is believed that a veneer hull, suitably lined with gas impervious fabric, will insure an almost perfect gas tightness.—*Aviation*, August 1, 1919.

The Lubrication of Ball-Bearings

By H. R. Trotter,[1] Hartford, Conn.

Ball-bearing lubrication is a subject of which little is known, and this is chiefly due to the fact, that there is no accepted method of determining the lubricating value of an oil or grease. As a step toward the development of a satisfactory method the author has devised an instrument for such a purpose, a brief description of which follows in this paper. The operating characteristics of a ball-bearing as related to the problem of lubrication are also discussed and the specifications for a satisfactory oil are given. The use of grease and graphite as a lubricant is next presented and the paper concludes with a suggested procedure for the analysis of lime-soap greases.

An investigation of existing literature on the subject of ball-bearing lubrication reveals the fact that up to date a comprehensive study of this particular phase of lubrication has not as yet been published. The efficient lubrication of the plain-sleeve type bearing presents, on the other hand, few difficulties, as the engineering world is in possession of an accumulation of data acquired during many years of patient study, experiment, and practice.

In 1885, Beauchamp Tower completed a series of experiments which he had made to obtain data regarding the behavior of a lubricant under various loads and speeds. These experiments were made at the request of the British Institute of Mechanical Engineers, and were later made the subject of a very thorough mathematical analysis by Prof. Osborne Reynolds. The outstanding feature of these experiments was the discovery of the wedge-shaped film of oil. Professor Reynolds later gave the rule for efficient lubrication which is that where two surfaces are in sliding contact a satisfactory film of oil cannot be maintained, unless the surfaces are at a slight inclination to each other.

The formation of such a wedge shaped film of oil can be described as follows: In Fig. 1 is shown a pan or tray (A) containing a small amount of oil. A flat plate (B) is loaded with weights (C). When in a stationary position, the surfaces of the plate and pan are parallel to each other, but if the plate is now pulled along the surface of the pan the leading edge will rise and the plate will float on an oil film with the surfaces at an inclination to each other. The oil film assumes the shape of a wedge as shown in Fig. 2.

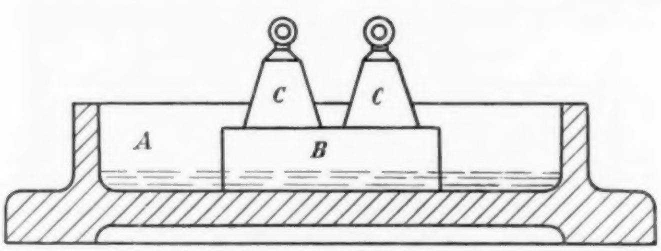


Fig. 1 Formation of Oil Film, Initial Stage

The Mitchell thrust-bearing, which is manufactured in Great Britain, and the Kingsbury thrust-bearing, made in this country, are designed to take advantage of this phenomenon and both have proven very successful.

Successful bearing operations is a problem that should be solved by the designer, and not by the lubrication engineer who acts in an advisory capacity after the bearing is in service. It must be admitted, however, that the average engineer is not in possession of the necessary data which would enable him to select the proper type of lubricant for his particular use. Nor has he the instruments or appliances to analyze a lubricant both physically and chemically.

The final choice of a lubricant is at best the result of a compromise between the engineer and the chemist. This compromise is very often unsatisfactory and due in part to the chemists' inability to thoroughly comprehend the engineer's problem and in part to the engineer's lack of chemical knowledge.

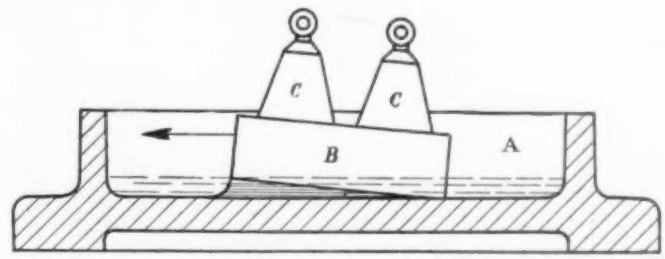


Fig. 2 Formation of Oil Film, Final Stage

The Testing of Lubricants

At the present time there is, unfortunately, no instrument which will accurately indicate the true lubricating value of an oil or grease, and until such an instrument is devised, the selection of a lubricant must be more or less a matter of guess work. A viscosimeter gives a comparative reading of the inertia of a liquid, but it does not indicate the value of a lubricant under working conditions. Furthermore, all authorities are not agreed on the desirable qualities of a lubricant. Many claim that a high surface tension is a requisite, and others lay great stress on adhesive qualities. All are agreed, however, that a lubricant should have the minimum of internal friction. Generally speaking, the requirements of a lubricant for the plain-sleeve type of bearing are a certain amount of adhesive quality to enable it to adhere to both the revolving and stationary surfaces. It should have sufficient body to withstand the pressures. The lubricant film will, therefore, consist of three layers, which in operation approximate the features of a ball-bearing in that one element is stationary, one rotating, and one an intermediate layer consisting of globules similar to the balls in a ball-bearing. From this description, the importance of body in a lubricant will be realized, and as the best and toughest material is required in the balls of a ball-bearing, so is body required in the intermediate layer of a lubricant.

Body in a lubricant cannot very well be defined. It seems certain that its effects are opposite to viscosity. Professor Kingsbury gives the following relations of viscosity and body. (Trans. A. S. M. E., 1903, page 147).

With increase of	Where the viscosity is effective the coefficient of friction	Where the body is effective the coefficient of friction
Pressure	Decreases	Increases
Speed	Increases	Decreases
Temperature	Decreases	Increases

The author has designed an instrument which may possibly be the means of obtaining data of value regarding lubricants. This instrument is shown diagrammatically in Fig. 3. The appliance consists of a revolving element driven by a small

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motor and a stationary element similar to a block used in a Mitchell or Kingsbury bearing with suitable means of obtaining readings of the inclination angle of the block to the revolving element.

At one time it was considered necessary to support the blocks in a Mitchell or Kingsbury thrust-bearing at a point behind its center of figure in order to secure the wedge of oil between the opposing surfaces. Furthermore, it was assumed that if such a block was centrally supported, it would possess no load carrying capacity. Independent experiments by Professor Kingsbury and Sir Charles Parsons established the fact, however, that a centrally pivoted block could carry considerable load. This was an important discovery, as most of the applications of Mitchell and Kingsbury thrust-bearings have been on marine propeller shafts where reverse rotation is necessary. It was the author is not certain as to the practical value of such an instrument, it is at least a step in the right direction.

Operating Characteristics of Ball-Bearings

The two cardinal points of successful sleeve-bearing operation are:

1 A design of such a type as will permit of the formation and preservation of an oil film

2 Selection of a lubricant that will provide a film of maximum strength with a minimum of internal friction

With a ball-bearing, however, the problem is not so easily understood, but the important points to be remembered are:

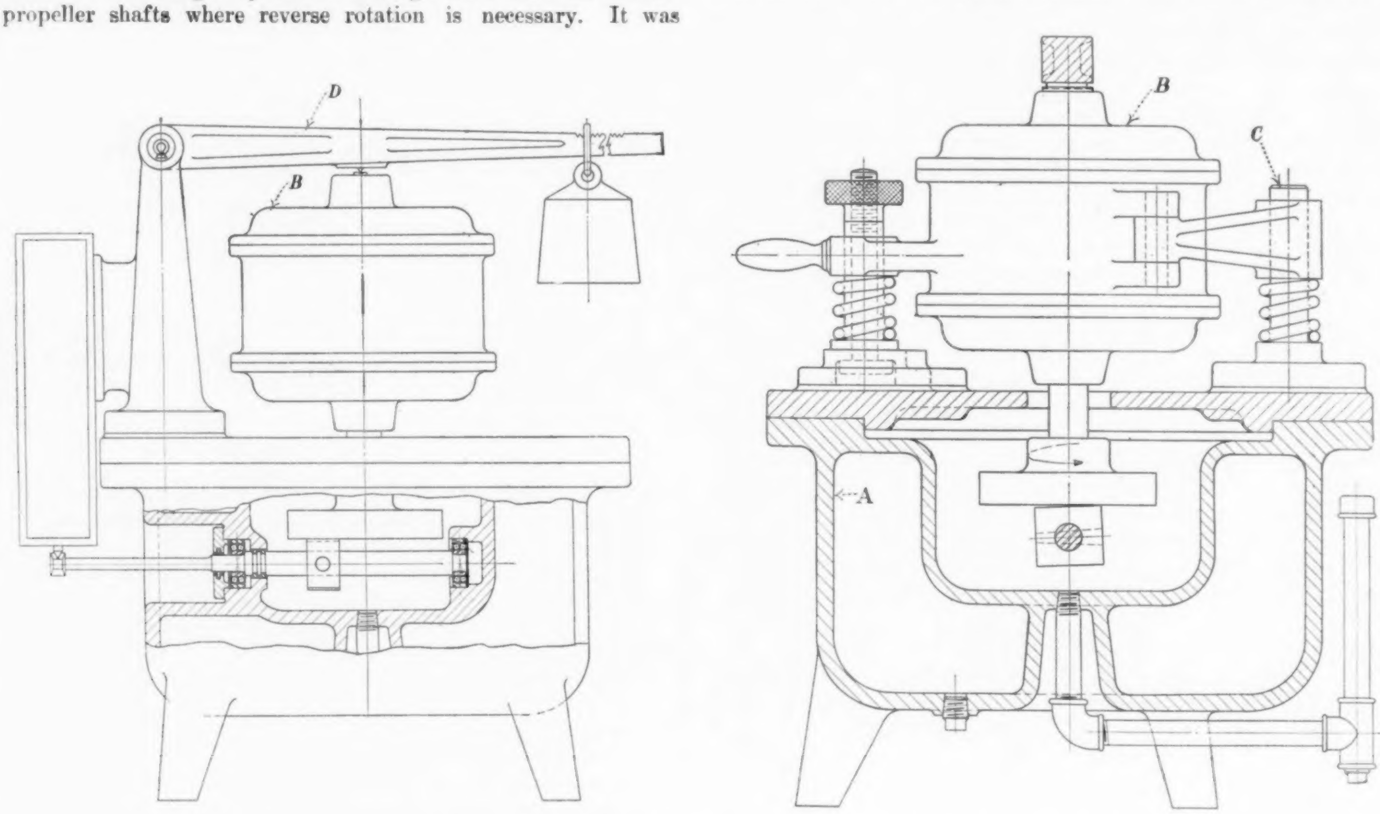

Fig. 3 Diagrammatic Sketch of Author's Device for Obtaining Data Concerning Lubricants

later found that with a centrally supported block, the wedge shaped film of oil was due to the change of viscosity of the lubricant when passing through the block. It will thus be seen that the angle, which the block assumes to the rotating member, gives an indication of the change of viscosity in a lubricating film when in operation.

Referring again to Fig. 3 (*A*) marks a casing consisting of an inner chamber which contains the lubricant to be tested and an outer chamber containing oil which is electrically heated and which transmits its heat to the inneer chamber. At (*B*) is shown a small electric motor with a shaft extension on which is placed a flange, the face of which is highly polished. The motor swings on a pivot (*C*) which allows the flange to take various positions with relation to the block thus enabling readings to be taken at various rubbing velocities. By means of the lever (*D*) various pressures can be obtained. The movement of the block is magnified by minimeters and transmitted to the dial indicator. Holes are drilled in the block and can be connected to a monometer to obtain pressure readings, or as there is practically no pressure difference, the holes can be connected to each other in such a manner that there will be practically no velocity through them. Temperature may be obtained at the leading and trailing edges of the block. Readings can be taken at constant speed with varying loads or with constant load at varying speeds. While

1 The coefficient of friction is practically constant throughout wide ranges of loads and speeds

2 Metal to metal contact (an oil film only possible at very high speeds when slippage may take place)

3 The coefficient of friction is lower in an unlubricated ball-bearing (at light loads and moderate speeds).

The first point is, of course, generally known, but the conclusion to be derived from this point has not been stated before to the author's knowledge, namely, the impossibility of an oil film between balls and races.

In Fig. 4 curve *A* shows the change of friction coefficient of a plain-bearing under constant load and varying speed. This curve is self-explanatory and shows that a satisfactory oil film is not formed till a certain speed is reached. In the same figure curve *B* gives the friction coefficients of a well-made ball-bearing, and shows that the friction loss of a ball-bearing is practically constant throughout wide ranges of speed. If an oil film were formed between balls and races, curve *B* would possess the same general characteristics as curve *A*.

The difference between the friction coefficient of a lubricated and unlubricated ball bearing is shown in Fig. 5. This property of a ball-bearing is not generally known, and should not be used as an argument in favor of operating ball-bearings

without lubrication. From the foregoing statements it should be evident that plain-bearings and ball-bearings possess such radically different characteristics that a true comparison is impossible. It naturally follows, therefore, that practically all the accumulated experience of the lubricating engineer is of little value when analyzing ball-bearing operation.

Requirements of a Ball-Bearing Lubricant

The use of a lubricant with ball-bearings is necessary to protect the highly polished surfaces of the balls and raceways, and to minimize the slight friction between the balls and ball retainer. The small amount of friction between balls and retainer

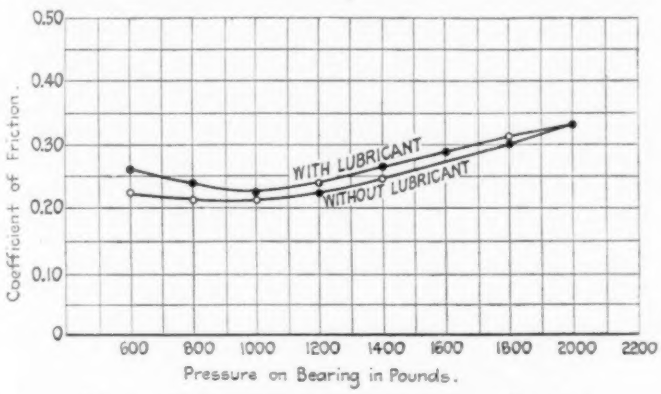

Fig. 4 Fiction Coefficient of a Plain-Bearing

can also be minimized by careful design. The principal requirement of a ball-bearing lubricant is chemical neutrality. The lubricant used must not contain over 0.10 per cent acid or alkali. There are many commercial lubricants on the market which come within this limit, but very few are acceptable because of their tendency to develop acid with age or when operating at high temperatures.

Most of the high grade oils can be used with safety, but many of the lubricating greases, while suitable for general purposes, are a positive menace to successful ball-bearing operation, not because of poor material used in the manufacture of greases, but because of the lack of scientific mixing methods. The manufacturer is in no way to blame for this condition, because he is making grease for general commercial use and not for ball-bearings. There are now on the market a few greases manufactured especially for ball-bearings, but, with one exception, all those tested by the author have proven worthless and clearly indicate the maker's ignorance of the requirements.

Experience shows that the most satisfactory lubricant for ball-bearings is a highly refined mineral oil having the proper viscosity and cold test for the installation. Greases should be used only where operating conditions require viscosities greater than can be obtained with a mineral oil.

Whenever a ball-bearing is operated at high speeds, it is not advisable to run it submerged in a lubricant, and provision should be made to supply the oil from a pressure system. If such a system is not available, good results may be obtained by a large-sight feed-oil cup. A few drops of oil per minute is all that is required.

At moderate speeds a heavy oil will generally give better results than a light oil. The substitution of a heavy oil for a light oil will generally result in a decreased operating temperature. This peculiarity may be explained by the fact that when the bearing is running at the actual operating speed, less opposition is offered to the rotation of the balls by the oil because of the inertia of the oil. In addition, there is less churning and frothing with its resultant air pockets. Air pockets in a lubricant act as insulators and prevent the transmission of the heat generated to the outer casing where it can readily be dissipated.

All mineral oils used on ball-bearings should be highly refined, filtered, and contain a minimum amount of acid, alkali or sulpho compounds, and in order to insure the use of such oils the following specifications are suggested:

Free acid (calc. as oleic acid), maximum, 0.10 per cent
Free alkali, absent
Ash, trace
Heat test (15 minutes at flash point), slight darkening, but no sediment
Flash point (Cleveland open cup), minimum, 300 deg. fahr.
Fire test, minimum, 350 deg. fahr.
Viscosity at 100 deg. fahr., Saybolt Universal

Light oil	100 to 200 sec.
Medium oil	200 to 300 sec.
Heavy oil	300 to 500 sec.
Extra heavy oil	More than 500 sec.

Free Acid Test. The test for free acid should be made in accordance with the method of the American Society for Testing Materials, which is as follows:

Accurately weigh 10 grams of the oil into a flask, add 50 cc. of 95 per cent alcohol which has been neutralized with weak caustic soda, and heat to the boiling point. Agitate the flask thoroughly in order to dissolve the free fatty acids as completely as possible. Titrate while hot with tenth-normal alkali, using phenolphthalein as indicator. Express results as percentage of oleic acid. 1 cc. N/10 alkali = 0.0282 gram of oleic acid.

Emulsion Test. This test gives a very definite indication of the presence of sulpho-compounds in an oil (sulphuric or sulphonic). There are several methods for carrying out this test, but for routine work, the following method for motor oil specified by the War Department in Specification No. 3502 issued April 24, 1918, should be followed:

One ounce of the oil shall be placed in a standard four-ounce bottle with one ounce of distilled water. The mixture shall be heated to a temperature of 180 deg. fahr. and then shaken vigorously for five minutes. After standing for one hour the oil must be clear and of the same color as before the test. All of the water must have settled and appear only slightly cloudy.

This method is simple and gives valuable indications as to degree of refinement of the oil. Highly refined oil shows a thin white line of demarcation between the oil and clear water below, thus indicating the absence of sulphuric acid compounds. Impure oil mixes permanently with water, appearing often as a curdled mass floating on milky water. The curdled portion contains what is frequently called a sulphuric acid soap and the extent to which it is present is an indication of the quantity of the "sulpho" compounds left in the oil, due to improper refinement. Oils containing appreciable amounts of these sulpho compounds are unsuitable for ball-bearings.

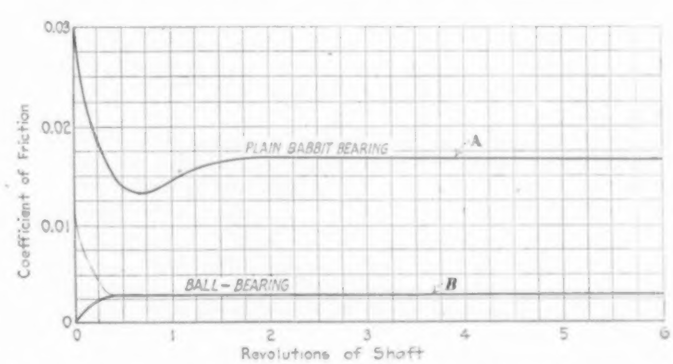

Fig. 5 Friction Coefficients of a Plain and a Ball-bearing

Heat Test. This test is conducted by heating a small portion of the oil in a flask or beaker up to the flash point and holding it at this temperature for fifteen minutes. A comparison is made between the heated and unheated oil. Highly refined oil darkens slightly but does not deposit sediment on standing twenty-four hours. Oils that contain sulphuric acid compounds turn black and deposit carbonlike substances. Such oils are not suitable for ball-bearings.

Inflammability Test. A flash point of 300 deg. fahr. (open cup) is the lowest limit considered safe for ordinary work and, on installations subject to high temperatures, oils having a flash point above 400 deg. fahr. should be used. The fire hazard is the factor to be considered in specifying the flash and fire tests.

Cold Test. For installations running at low temperatures asphaltic base or low pour-test oils are recommended as this type of oil shows pour tests of 5 deg. fahr. or below, while the paraffin base oils do not ordinarily run below 30 or 35 deg. fahr.

Lubricating Greases for Ball-Bearings

Most of the high-grade mineral oils conform quite closely to the above specifications. In connection with lubricating greases, however, the problem is more difficult. Many of the greases now on the market are entirely satisfactory for general purposes, but lack certain characteristics which experience shows to be highly important for successful ball-bearing lubrication. Tables 1, 2, and 3 show the variations to be found in a number of lubricants on the market, and it includes a sufficient number of analyses to show characteristic variations in the different types of greases available.

A large number of greases contain lime-soap as thickeners, a few are of the soda-soap type, while others are a combination of both. The lime greases are valuable in that they can be used without harmful results where moisture is present. Their consistency, however, is more easily changed by heat than greases of the soda type.

Using the tests previously mentioned as a basis, we can very easily arrive at a suitable specification which will ensure the production of lubricants suitable for ball-bearings without putting any undue burden on the lubricant manufacturer. The following specifications are accordingly suggested:

- Free acid (calc. as oleic acid), maximum, 0.10 per cent
- Free alkali (calc. as sodium hydroxide), maximum, 0.10 per cent
- Free lime (calc. as calcium oxide), maximum, 0.5 per cent
- Neutral saponifiable oil, maximum, 1.0 per cent
- Viscosity of mineral oil (minimum 200 sec. Saybolt Universal 100 deg. fahr.)
- Abrasive particles (sand, etc.), absent.

The determination of acidity in a grease containing lime-soap requires special treatment and the following modification of Marcusson's method is strongly recommended:

Ten grams of the grease are carefully weighed into an extraction flask and dissolved in 88 deg. gasoline by shaking cold (it is well to dissolve cold as by heating or boiling some of the free lime may combine with the free acid). Allow the soap to settle, and pour clear gasoline solution on medium large filter, without stirring the soap, treat the insoluble soap, lime, etc., again with gasoline thoroughly shake and allow to settle clear, pour on filter paper and when filtered wash soapy residue into filter paper and wash several times with gasoline until all soluble is washed out. Filtrate and washings are caught in Erlenmeyer flask of sufficient capacity, the gasoline solution is slowly distilled off on electric hot-plate, being careful not to carry down too far so as to break up the oils.

The residue is washed into a stoppered bottle with a small amount of gasoline and 50 cc. of 50 per cent neutral alcohol added and titrated with standard N/100 sodium hydroxide solution, shaking the mixture thoroughly after each drop of solution is added, using phenolphthalein as an indicator. By this method, the acid content can be determined within 0.02 per cent, calculated as oleic acid.

Ball-bearing manufacturers are quite agreed that the limit of free acid in a grease should not exceed 0.10 per cent calculated as oleic acid, and from the Tables 1, 2, and 3 it is evident that there are plenty of greases available which meet this requirement.

It is essential that the grease be comparatively free from unsaponified fatty oil, or as expressed in the analyses, "neutral saponifiable oil." This specification is imposed because the unsaponified fatty oil has a tendency to become rancid or develop an acidity with age in service, particularly when operating at high temperatures. We have established a limit of 1.0 per cent, and the above tables show that this can be met in most of the compounds which are suitable in other respects.

One feature of grease lubrication which cannot be too highly emphasized is the importance of using a high-grade mineral oil conforming to the tests for purity as previously outlined. A grease may be perfect in every other respect, yet if a poor grade of mineral oil is used, the life of the bearing will be shortened.

Some manufacturers take advantage of the fact that a grease made with kerosene looks much the same as one containing high-grade oil and cheapen their product by using inferior light oils. It is desirable that a highly refined oil showing about 200 sec. viscosity Saybolt Universal at 100 deg. fahr. be used in the ordinary grease formula.

TABLE 1 LIME-SOAP GREASES

Mark	Mineral Oil per cent	Neutral Saponifiable Oil per cent	Lime Soap (calc. as calcium oleate) per cent	Free Lime per cent	Free Acid (calc. as oleic acid) per cent	Moisture and Undetermined per cent.	Melting Point deg. fahr.
130,849	67.26	0.42	27.18	1.53	0.05	3.56	210
131,859	84.56	0.10	10.72	0.15	0.04	4.43	190
131,860	86.35	0.32	8.76	0.09	0.04	4.44	165
131,574	88.31	1.55	8.15	0.19	0.07	1.73	103
141,537	74.04	0.95	19.13	0.21	0.03	5.64	182
142,543	74.49	2.03	17.94	0.30	0.08	2.16	170
141,544	82.00	4.72	10.72	0.03	0.07	2.46	151
132,255	65.76	5.64	21.29	0.53	0.76	6.02	202
132,254	81.62	0.56	15.85	0.20	0.14	4.65	152
141,533	78.88	1.95	17.82	0.22	1.16	2.94	157
141,535	75.46	1.11	17.82	0.37	0.51	4.73	177
143,098	83.09	1.10	13.21	0.23	0.30	2.07	174

TABLE 2 LIME SODA-SOAP GREASES

Mark	Mineral Oil per cent	Neutral Saponifiable Oil per cent	Lime-Soap (calc. as calcium oleate) per cent	Soda-Soap (calc. as sodium oleate) per cent	Free Acid (calc. as oleic acid) per cent	Free Alkali (calc. as sodium-hydroxide per cent	Free Lime per cent	Moisture and Undetermined per cent	Melting Point deg. fahr.
134,705	74.28	0.42	19.09	1.78	absent	0.014	0.65	3.76	205
134,710	77.30	....	0.71	19.76	absent	0.013	0.52	1.697	205
134,711	85.38	0.40	11.02	0.95	absent	0.002	0.13	2.118	192
134,712	90.44	0.53	6.80	0.77	absent	0.006	0.04	1.414	114
134,713	84.26	0.50	2.17	11.04	absent	0.002	0.22	1.808	160
141,536	72.82	1.20	18.42	1.88	0.57	absent	0.05	5.06	186
141,538	84.70	2.15	9.12	1.14	0.42	absent	0.40	2.43	183
141,540	78.00	3.95	14.34	1.52	absent	0.004	0.57	1.606	189

TABLE 3 SODA-SOAP GREASES

Mark	Mineral Oil per cent	Neutral Saponifiable Oil per cent	Soda-Soap (calc. as sodium oleate) per cent	Free Alkali (calc. as sodium oleate) per cent	Free Acid (calc. as oleic acid) per cent	Moisture and Undetermined per cent	Melting Point deg. fahr.
132,736	98.13	0.60	0.70	absent	0.05	0.52	Fluid at r'm.temp
132,738	95.02	0.32	3.69	0.01	absent	0.96	98
134,136	92.60	0.30	6.10	absent	0.06	0.94	110
135,863	53.60	28.88	5.17	absent	0.14	12.21	108

In view of the high polish necessary on ball-bearings, the elimination of abrasives such as sand particles, etc., is manifestly important.

At the present time, there is no generally accepted method for determining the consistency or melting point of a grease. Grease manufacturers have adopted systems of nomenclature peculiar

to their product, but not directly comparable to any other manufacturer's product. In the absence of a standard test, the adoption of the method for determining the melting point described by Gillett is urged. (See *Journal Industrial and Engineering Chemistry*, 1909, page 351.)

This method makes use of an open capillary tube 4 mm. inside diameter and about 8 cm. long, graduated at 1 cm. and 5 cm. from one end. The tube is stuck into the grease, and if necessary, suction is used at the same time to draw up a plug of grease 1 cm. into the tube. The tube is then attached, with a rubber band, to a thermometer so that the grease plug is beside the bulb. The thermometer and tube are immersed in a beaker of water so that the bottom of the tube is 5 cm. below the surface of the water, and the water is heated at a rate of 3 to 4 degrees per minute. When the melting point is reached, the plug which is under a pressure of 5 cm. of water, slides upward in the tube.

By itself, this test means very little, but when made in conjunction with a complete analysis of a grease, it enables one to check up the uniformity of the manufacturer's product on various lots of the same grade and gives some idea of the temperature under which the grease will operate. The melting point as determined above is dependent upon the nature and amount of soap, oil, and water in the grease as well as the processes used in combining the various constituents of the grease.

It is also desirable to keep the free lime content of the grease down to a minimum as any excess detracts from the lubricating qualities of the grease. Experience indicates that 0.5 per cent is a desirable limit. In some of the greases that the author has examined, small lumps of free lime were discovered to be distributed throughout the grease.

The highest grade ball-bearing greases are put through a milling process after compounding. This treatment insures very intimate mixing of all constituents and pulverizes any chance impurity to an impalpable powder. It is strongly recommended that all greases for ball-bearings be so treated.

Graphite as a Lubricant

Graphite, despite its unctious qualities, cannot be regarded as a true lubricant. It can, however, be used with success in plain bearings as it fills in the interstices in the bearing surfaces and allows the true lubricant to operate efficiently. A modern well-made ball-bearing with mirror-like finish has, however, practically no interstices in the balls and raceways. A perefectly finished ball shows no scratches when magnified 100 diameters and furthermore, were there irregularities present, graphite would not eliminate them as there is considerable difference between the sliding action of a plain-bearing and the rolling action of a ball-bearing.

Graphite, moreover, has a tendency to pack in the ball retainers and raceways, and a bearing which has been lubricated with graphite grease generally has a distinct wavy appearance in the ball paths. A recent brief test of a grease containing colloidal graphite revealed the fact that while the graphite did not pack in the raceways, and the wavy ball paths were absent, the complete raceway presented a burnished appearace quite different from that obtained by the use of ordinary greases. The graphite packed hard in the ball retainer and could not be removed by dipping in gasoline.

The use of graphite in ball-bearings cannot, therefore, be regarded as beneficial, and its application is purely a question of economies. Its use in ball-bearing automobile transmissions and rear axles is advisable only if the increased efficiency and life of the gears offsets any possible harmful effect on the bearings.

Analysis of Lime-Soap Greases

The procedure for analyzing lime greases is not a simple one and the following suggested form may prove of interest. The ordinary constituents of a lime-soap grease are:

$$\left.\begin{array}{l} a \text{ Mineral oil} \\ b \text{ Saponifiable oil} \\ c \text{ Free lime} \\ d \text{ Free fatty acid} \\ e \text{ Moisture} \\ f \text{ Soap.} \end{array}\right\} \text{Original State}$$

Determination of Total Fatty Matter. Weigh 10 grams of the grease into 250 cc. extraction flask, add 50 cc. water and 5 cc. of hydrochloric acid. Boil on hot-plate for one hour or until the soap is completely broken up. Make sulphuric ether extraction, leaving,

$$\left.\begin{array}{l} a \text{ Mineral oil} \\ b \text{ Neutral saponifiable oil} \\ d \text{ Fatty acid.} \end{array}\right\} \text{Second stage}$$

Determination of Total Acidity. Add 50 cc. of neutral alcohol, heat under reflex condenser for fifteen minutes to dissolve fatty acids and titrate with standard alkali using phenolphthalein as indicated. The standard alkali used in the titration is calculated to oleic acid which gives a total of fatty acids combined as soap and free fatty acids existing in the grease, leaving

$$\left.\begin{array}{l} a \text{ Mineral oil} \\ b \text{ Neutral saponifiable oil} \end{array}\right\} \text{Third stage}$$

Determination of Neutral Saponifiable Oil. To the contents of the flask from the above determination, add 25 cc. of standard alcoholic caustic potash solution and boil under reflex condenser for two hours. Titrate the excess of caustic potash with standard hydrochloric acid and calculate the number of miligrams of caustic potash used up by the neutral saponifiable oil. The neutral saponifiable oil is then calculated from the saponification number, leaving

$$a \text{ Mineral oil} \} \text{ Fourth stage}$$

Determination of Mineral Oil. Add 10 cc. of standard alcoholic caustic potash solution to the contents of the flask used in the previous determination and boil under reflex condenser for one-half hour. Cool and make petrolic ether extraction. Ether extract contains the mineral oil.

Determination of Ash Content. Weigh 10 grams of grease in a platinum dish. Burn to ash over gas burner. Residue may contain lime, lead, sodium, sand, potassium, silicates, iron, aluminum, mica, talc, or mineral filler. Weigh residue and add hydrochloric acid. Heat and filter. Residue contains sand, silicates, mica, talc, etc.

The filtrate contains iron, aluminum, calcium, sodium, potassium, etc., and should be made alkaline with ammonia, then boiled and filtered. Residue is iron and aluminum. Filtrate contains calcium, sodium, and potassium. Add excess of ammonium oxalate to filtrate, and filter. Residue contains lime in form of calcium oxalate, filtrate contains sodium and potassium.

While the bases used in the soap may be determined by the usual chemical methods as indicated above, micro-chemical methods are quicker and more delicate for qualitative tests and in some instances the latter method represents the only practical means of determining very small amounts of the bases used. Chamot, in his book on Elementary Chemical Microscopy, gives a complete and detailed account of the methods to be used in microscopic analysis.

In conclusion, the author would like to point out the need for further investigations to obtain data so that lubricating grease specifications may be standardized. The lubrication problem is essentially a chemical problem and we should welcome the assistance of the chemical societies in this matter.

The railroads have at last shown a net gain to the government. The operating results for the month of July of practically all Class 1 railroads and terminal companies under federal operation indicate that this net gain will run to approximately \$2,000,000. The net operating income for the month of July, 1919, was about \$77,000,000. The indicated net gain to the government for July is obtained after allowing one-twelfth of the annual rental due the railroads. The net loss to July 31, 1919, was \$290,526,307.

Mid-Continent Section Meeting of A. S. M. E.

A Group of Papers Relating Mainly to the Oil Industry, Presented at the First Meeting of the Mid-Continent Section of the Society at Tulsa, Okla.

One of the newest Sections of The American Society of Mechanical Engineers is located in the heart of the famous mid-continent oil fields, with headquarters at Tulsa, Okla. This Section covers the large territory included in Oklahoma, Kansas, Northern Texas, and a portion of Louisiana and Arkansas. While its meetings will be devoted to general engineering subjects, it is expected that many of the papers will relate to the betterment of the mechanical phases of the petroleum industry. On May 23, 1919, an all-day meeting was held, at which the group of papers here abstracted was presented. A feature was made of the inspection of airplanes which had been brought from the Air Service Center, No. 2, Romorantin, France, by Lieut. E. E. Ives, recently of the U. S. Air Service, who gave a brief paper, here included. The Mid-Continent Section is now planning a second meeting to be held the latter part of October, announcement of which is in this number.

THE EDUCATION OF A PETROLEUM ENGINEER

By J. H. Felgar,[1] Norman, Okla.

In discussing this topic, the writer desires, first of all, to call attention to Dr. Mann's preliminary report on engineering education in which there was discussed the replies received from a questionnaire sent out to a large number of employers of technical men, and to technical men themselves. The replies indicated the rather startling conclusion that the factors which go to make up technically educated men, able to compete in their professions, are mainly personal qualifications and not technical knowledge as might have been supposed. This report has naturally led to a general consideration of the requisites of a technical education.

There are certain fundamental studies which form the backbone of any engineering course and these are mathematics through calculus, one year of college physics, a full treatment of applied and theoretical mechanics, a full course in strength of materials, and a carefully-given course in statics and dynamics. To these might be added a year in chemistry and a course in English composition and literature.

There should also be included in the curriculum a course in business law and contracts, elementary accounting, and the fundamentals of cost accounting. These three courses make a foundation upon which a knowledge of business administration could very well be built.

No engineering course is complete without a year of mechanical drawing, and in addition to this, a course in descriptive geometry develops constructive thought and imagination. Shop work and elementary surveying are also essential.

There are, of course, the subjects taken just for their educational value and the satisfaction in the knowledge gained, and there are few engineering educators who would not appreciate an opportunity for their students to take a course in history, political science, sociology, literature, and art.

Coming now more particularly to the subject of petroleum engineering from the production standpoint, this should include scientific work in locating new fields, location and drilling of wells, conservation of the product, whether oil or gas, the piping of oil to storage and gas to the consumption point. Following the year of fundamental chemistry, there should be a course in quantitative analysis and organic chemistry with special attention to the specific problems of oil and gas. This course is for the general education of the technical student entering this field and should, therefore, be included whether any application is made of it or not. In the second semester of the freshman year, a course in the elements of surveying should be started, continued through the more advanced subjects and concluded by a practical course in the field. In the sophomore year the student should begin the study of the elements of geology, and sufficient work in higher geology should also be given so as to permit of his entering the field and seeking employment in the geology department of any oil company.

The moment that one approaches the field of petroleum engineering he realizes that there is a demand for training in mechanical engineering, and such a training should comprise the fundamentals of steam machinery, including engines, pumps, compressors, etc., and also the fundamental principles of gas and gasoline engines. A course in the study of transmission of oil and gas through pipe-lines is also worthy of a hearing, and it would not be amiss to acquaint the student with classes, types and methods of drilling.

Electricity and electrical machinery are finding a place in the production of oil, and for this reason a petroleum engineer should be familiar with the fundamental principles of electricity as presented by a course in electricity and magnetism. He should also have a knowledge of the workings and principles of electrical machinery, gained through laboratory experiments. Such a course as this will be found in practically every non-electric course in any technical school throughout the country, and will fulfill the fundamental needs in a course in oil and gas production.

Turning to the refining standpoint, there is no doubt but that from the fundamental outline already discussed, the technical work could be filled in from the departments of chemistry and engineering. In mechanical engineering it would be necessary to begin with the fundamental course in steam engines and boilers, taking along with it some laboratory work in the operation and efficiency of steam machinery, together with the discussion of the transmission, metering and flow of fluids in pipes and a knowledge of the machinery necessary to produce this flow. It would be well to include a careful study of the economy of burning fuels under different types of boilers, including their cost and construction, and to obtain a knowledge of the fundamentals of heat transfer, a thorough course in thermodynamics should be included, which should take up in detail the different engine cycles, compressors, and the specific heat of different substances, taken separately, and a mixture of these substances; also a study of the saturation tables of different fluids at different temperatures and pressures, a study of the specific gravity, etc. This course can be made as comprehensive in the theory of heat as time will allow, and is, without doubt, a fundamental course. There could also be included a course in the principles and operation of oil and gas engines.

The foundation work in chemistry should be continued, including a course in quantitative analysis which follows the first year's work taken by all students. A fundamental course in organic chemistry and another in organic preparation could also be given. Qualitative analysis should likewise be more carefully studied, for no better course exists to develop insight into the scientific spirit than a study of physical chemistry and physical-chemical measurements. Along with all this material, the study of petroleum technology could be begun. The studies dealing more intimately with petroleum engineering could be given in as many subdivisions as there was time to devote to them, and would include lectures on theory and practice of petroleum refining, petroleum products, natural gas and natural-gas products, and the analysis of petroleum products, coal tar, oil shales, and natural gas. The details of petroleum refining could be taken up in a separate course, each followed with laboratory work to emphasize the theory. Research problems might

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also be given and inspection trips should be taken to study actual conditions. The laboratory work would also include the carrying out of the refining process in a small but complete refinery of about one to five barrels capacity.

Although such an undergraduate course is intended primarily to give a fundamental training in petroleum technology, nevertheless, the student would not find himself unnecessarily handicapped if an opportunity presented itself in other allied fields.

Even a brief study of this undergraduate course, by anyone interested in petroleum engineering, will immediately disclose the fact that many of the problems, which he had in mind for such a course, could not be considered by undergraduate students, but must be solved by the work of graduates. Each will realize also that any technical course is perfected through development, or through a process of evolution, as a biologist would call it, and if the engineering profession can come to some reasonable agreement as to what fundamental general training and professional work should be included in the undergraduate course, then such agreement will immediately eliminate the more advanced problems for graduate study. The problem of getting this material into the course can be attacked in two ways: first, by requiring a year of general training before entering the technical school, in which considerable of the preliminary work will be carried, leaving room at the end for these more advanced classes in technology; or second, by the addition of a stiff graduate year to the course already outlined, in which the advanced problems could be approached.

In conclusion the writer wishes to present the outlines of three courses, the first giving the essentials of any technical course, as combined with suggested professional work adapted to prepare for the petroleum field, the second, a suggested course in petroleum-production engineering and the third, a suggested course in petroleum-refining engineering.

The Essentials of a Technical Course[1]

First Year

Chemistry	5	Analytical Chemistry	3
Algebra	3	Analytical Geometry	5
English	3	English	3
Drawing	2	Drawing	2
Shop	1	Shop	1
		Surveying	3
Total	14	Total	17

Second Year

Calculus	3	Calculus	3
Physics	4	Physics	4
Descriptive Geometry	2	(Courses especially related to the petroleum industry)	11
(Courses especially related to the petroleum industry)	9		
Total	18	Total	18

Third Year

Mechanics	5	Strength of Materials	4
Graphics	1	Testing Materials	2
Elementary M. E.	3	Hydraulics	3
Economics and Business Administration	3	Elementary Accounting	2
(Petroleum Industry Courses)	8	(Petroleum Industry Courses)	7
Total	20	Total	18

Fourth Year

Electrical Machinery	3	Electrical Machinery	3
Electrical Laboratory	1	Electrical Laboratory	1
Adv. English Composition	2	Engineering Contracts	2
Cost Accounting	2	Organization and Management	2
(Petroleum Industry Courses)	10	(Petroleum Industry Courses)	10
Total	18	Total	18

[1] The courses in parenthesis apply only to such as are especially adapted to prepare one for the petroleum field and include chemistry, geology, mechanical engineering, civil engineering, etc. The course in petroleum production requires somewhat different studies than that in petroleum refining.

A Suggested Course in Petroleum-Refining Engineering

First Year Common to All

Second Year

Quantitative Analysis	3	Petroleum Chemistry	5
Organic Chemistry	5	Organic Chemistry	2
Gas and Gasoline Engines	3	Adv. Quantitative Analysis	3
Total	11	Total	10

Third Year

Elementary Geology	5	Elementary Geology	5
Physical Chemistry	3	Physical Chemistry Measurements	3
Petroleum Chemistry	3	Chemical Technology	2
Total	11	Gas Analysis	3
		Total	13

Fourth Year

Steam Machinery	2	Field Work	3
Petroleum Chem. Lab.	3	Petroleum Research Chemistry	5
Petroleum and Gas Transmission and Measurement	3	Total	8
Total	8		

A Suggested Course in Petroleum-Production Engineering

First Year Common to All

Second Year

Advanced Surveying	4	Surveying Field Practice	2
Elementary Geology	5	Elementary Geology	5
		Topographical Drawing	2
Total	9	Oil and Gas Engines	2
		Total	11

Third Year

Quantitative Analysis	3	Organic Chemistry	5
Elementary Mineralogy	5	Geological Map Interpretation	5
Steam Machinery	3	Adv. Mineralogy	3
Total	11	Total	13

Fourth Year

Economy Geology	5	Peroleum and Gas Geology	5
Oil and Gas Transmission, and Measurement	3	Petroleum Chemistry	5
Total	8	Total	10

THE TANK CAR MAINTENANCE PROBLEM

By PAUL BATEMAN,[1] COFFEYVILLE, KAN.

SINCE tank cars constitute a large item of initial expense to almost every producer and marketer of petroleum products, it is of some importance that they be maintained at a point of greatest efficiency with minimum up-keep expense.

As an engineer and designer for several years, in the employ of two of the largest car builders in the country, it was a matter of circumstance that one of the outstanding ideas of car builders was forcibly brought to my notice. . That is, in substance, design *something different*. The best engineering practice is sometimes made subservient to the principle of designing something on which a claim for a patent may be made.

This practice has resulted in innumerable types of cars, each type with its own variations, and has greatly complicated the problem of maintenance of equipment. Repair shops have been called into existence by the impossibility of car owners carrying a sufficient variety of parts to repair their cars properly. Although there are some few concerns which employ experienced repair men, the owners of cars must in general trust to inefficient labor to perform work that requires specialized knowledge and experience.

Behind the experience, also, there must be knowledge, not only knowledge of how to make repairs, but of why the part requires repairs and of how to prevent a recurrence of the same trouble.

[1] Superintendent, Peoples Tank-Line Co. Assoc.-Mem. Am. Soc. M. E.

To make this clear we will refer to Fig. 1 showing the end of the underframe of a car. There are innumerable variations in the end structure, but the principle must remain the same in all.

Repair of Friction Draft Gear

The yoke, Fig. 1, is riveted to the butt end of the coupler and contains certain friction parts, which, in buffing, are compressed by the coupler against stops, or lugs, riveted to the longitudinal beams, or sills. In pulling, the yoke is brought into play and performs the same duty in a reverse direction, by compressing the friction parts against the front stops or lugs.

When originally installed the "friction draft gear" is provided with sufficient travel to enable the full capacity of the gear to be utilized. Any shock in excess of the capacity of the gear is absorbed by the horn of the coupler striking against the buffer

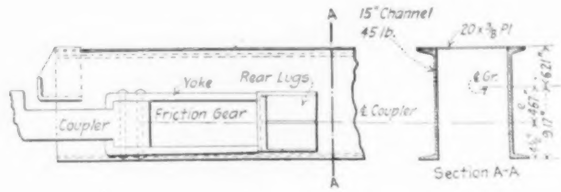

Fig. 1 End of the Underframe of a Car

on the end of the sills, after the gear is compressed to its full capacity.

The gear, as installed, is not at the center of the sills, due to details of construction based on truck clearances and the necessity of keeping the center of gravity of the loaded car as low as possible and there is approximately a 200,000-lb. shock on a 13 in. to 15 in. girder with an eccentricity of about 4 in. to 6 in. Any shock above the absorption capacity of the gear is absorbed by a direct blow against the fully-compressed gear which now

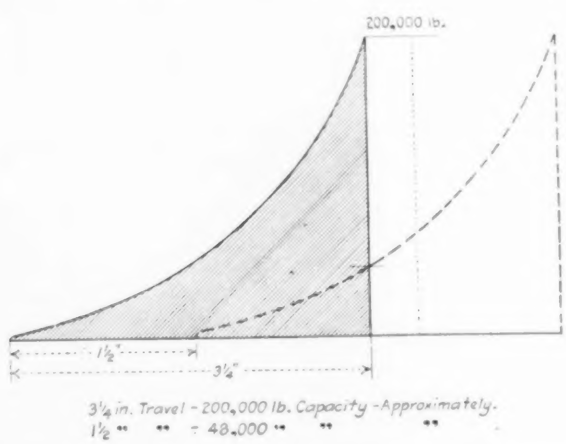

Fig. 2 Composite Compression Diagram of Draft Gears

acts as a rigid block. When wear on the friction elements develops, the end clearance betweene coupler and buffer block is eliminated and the impact load in excess of the gear capacity is received by the buffer. The gear, as originally installed, gives protection to the car, but when the friction parts wear, more and more of the impact load is directly transmitted to the buffer. As the latter has relatively little resiliency, it is only a question of a short time before it is broken, thus bringing the full load on the gear and thence directly to the sills. The obvious result is that the sills spread and buckle, or else the rivets on the rear draft lugs are sheared, sometimes both. The usual procedure has always been to say, "Oh, let it ride, the sills are all right, we'll fix it sometime." When it is finally released for repairs the first and only thing done is to put on a new buffer and let the worn-out gear alone.

If the gear has worn so that the first $1\frac{1}{2}$ in. of travel has become non-effective, there will be left only $1\frac{3}{4}$ in. of useful travel of the original $3\frac{1}{4}$ in., giving a retarding value of only about one-fourth of the capacity of the gear. (Fig. 2.) With the full load of a moving train, having a possible buffing shock up to 1,000,000 ft-lb., it is not hard to imagine the effect on the new buffer casting.

This is not an isolated case but is the usual procedure all over the country, not alone with the refiners, but also with the railroad companies and even some of the private repair shops.

As we are dealing with buffer forces, we have kinetic energy, which does not permit of the same assumption for fiber stresses as in the case of static loads. Under static loads we can figure a column at its full value, with each of the fibers bearing an equal portion of the load. Under our conditions, however, we have two variable forces, one along the center line of the coupler and the other along the center line of buffer impact, the latter after the frictional resistance of the gear has been absorbed. In addition we have the forces compounded by secondary forces which cause torsional stresses. These latter are caused by inequalities of tracks, different heights of couplers, impacts on curved track, couplers being off center, etc. We term them secondary forces,

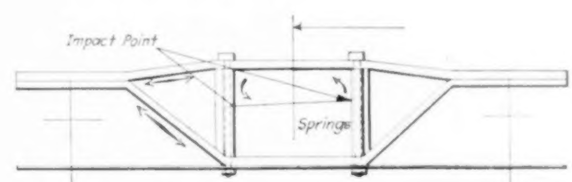

Fig. 3 Arch Bar Truck Construction

but they are really as much a part of the primary forces as are any others.

In tank car design, we do not have to consider the deflection due to loading on account of the loads usually being concentrated at the bolsters and thence transmitted directly to the truck, so all we have is the compound load due to conditions previously mentioned.

The above case, as illustrated, is indicative of the usual methods employed in making repairs. No thought is given to the cause. The best way to make repairs, of course, is to prevent the necessity. However, in conditions as they are, the best procedure is to remove the slack travel of the coupler by renewal of necessary parts and by placing shims between the gear and the lugs. After that, see that the correct position is maintained.

Truck Repairs

Reference to Fig. 3 shows the usual design of arch bar truck construction and the lines of force with their attendant results. We will suppose a loaded car to be in a rapidly-moving train, when an emergency application of the brakes is made.

The braking power is from 70 per cent to 90 per cent of the light weight of the car which, in a 38000-lb. car of 8000 gal. capacity, loaded with gasoline, is 30 per cent to 40 per cent of the total weight of the car. The result is that the trucks receive a direct load at the center plate due to the inertia of the entire loaded body of car at whatever speed it is traveling.

It has always seemed inconsistent that one part of the car—the sills, through the coupler—should be used to start the car, and another and much lighter part—the brakes operating on the trucks—should be used to stop it. The writer sees no way, at the present time, to improve the basic principle of this.

The resultant tendency in brake application is to transmit a load to *one* side of the center plate and generate torsional stresses tending to rotate the bolster. This load very naturally comes on only one side of the truck springs, which are intended always to act as a unit. The result is that the springs compress unequally and throw the bolster against the columns with unequal bearing. This causes failure in the columns by tearing the column bolt

through the wearing surface of the column. A condition of this kind is usually caused by neglect in allowing nuts of column bolts to become loose, thus permitting the arch bars to spread and allowing excess clearance. Quite frequently the cars, as originally built, have entirely too much clearance.

The material wear of columns and of the column guides on the bolster should be taken up by placing shims on one column or else on the column guide on the bolster. This is almost never done as it requires that the truck be practically dismantled.

Another cause of trouble is the rapid rounding of curves at which time the loaded car seeks a tangent and the trucks must follow the rails. That causes the bolsters to exert more pressure on one set of springs than on the other, thus allowing the springs to slip and quite frequently lose out. Improper side bearing spacing and clearance are very usual causes of truck failure and also cause derailment.

The principal instructions would seem to be to keep the truck tight and see that wooden shims, above or below springs, are renewed at sufficient intervals to insure that they are solid. The shims are made of seasoned oak but they decay very rapidly and allow the springs to settle into them, thus increasing clearances to an unsafe margin. Side bearing clearances must be kept at the proper point, $\frac{1}{8}$ in. to $\frac{1}{4}$ in. between top and bottom.

Repair of Tanks

Of the tanks proper little need be said except that all *indications* of leaks should be immediately looked into as stains on the *outside* usually mean that the caulking edge of the sheets and rivets on the *inside* has deteriorated. The tank should not only be caulked on the outside but more especially on the inside. It might be stated that caulking on the inside is almost never practiced except in the shop where its necessity is understood. The fact that inside caulking is obligatory, under Bureau of Explosives' Rules, seems to be overlooked. Leaks are quite commonly caused by deflection of the sheets of the unsupported end portion of the tank which causes distortion of the sheets at riveted joints.

The safety valves ordered to be used have always been a source of wonder to the writer, particularly as to why it seemed necessary to provide 40 sq.in. to safety valve outlet surface while the largest locomotive using superheated steam and a pressure of up to 250 lb. per sq. in. has only about 10 per cent of this area. The Master Car Builders Association has designed a device using a spring balance to determine the proper point at which to set the valve. Inequalities of bearing surface on the valve seats seem to be overlooked, consequently there is practically no guarantee that the valves will hold any pressure whatever.

All valves should be removed and ground in with emery in oil, then set to the proper point under a test by compressed air. The valve question is not only a maintenance problem but one in design, which we hope will have the attention of qualified engineers.

The advisability of keeping cars well protected by paint is too well known to require more than passing comment. That comment is mostly directed toward the policy of merely making the cars a good advertising sign board instead of seeing that the painting is properly done. Cars, particularly the tanks, should be thoroughly cleaned preparatory to painting as the improperly cleaned car will not hold the best paint made. My company has found it advisable to put the problems of painting up to the paint manufacturers, using their knowledge and experience in connection with our own.

One of the greatest causes of tank cars being neglected is the attitude of certain railroads, particularly at competitive points. When an inspector refuses a "Bad Order Car," a competing road's inspector will take it and so drum up business for his road. If it is impossible to run the car in its condition as accepted, temporary repairs are made. In fact, anything is done that will get it out of the yard at the point of origin. The owner is very grateful to the railroads accepting the car and consequently the accommodating railroad gets the future business.

This policy can have only one result, and that is evident when it is stated that the policy is pursued in endless chain fashion, the original road accepting cars that even the first offending road refused to handle.

INSPECTION OF AIRPLANES AT ROMORANTIN, FRANCE

By Lieut. Earl E. Ives,[1] Tulsa, Okla.

This paper relates to the inspection of airplanes at Air Service Production Center No. 2, Romorantin, France. All of the American-built planes which were used abroad were De Haviland-4s. They were shipped to Romorantin in a semi-assembled condition, there to be uncrated, set up, tested, and flown to the battle line. The plant in which this work was done had a floor capacity of 120 machines with wings on, and 75 to 100 machines without wings. In addition there was ample room for uncrating 50 machines a day and storage capacity for all this material. An airplane repair shop and a motor repair shop, each of the same size as the assembly plant, operated as auxiliaries to the assembly work.

When a machine was first uncrated an inspector was on the job with a handful of red rejection cards and repair shop cards. If defective material was found it was marked and the disposition to be made of it was indicated on the red card; that is, it was labeled "repair" or "salvage," as the case might be. If no trouble was found these first inspectors put a card on the machine which gave it the right to remain on the assembly floor.

Inspection in Fuselage Department

When the assembly work began the inspectors in the Fuselage Department went over every part of the machine. In checking up the machine for alignment the following rule was observed: "With the upper longerons level in the pilot's cock-pit, the motor bed should be level. A line parallel to and $16\frac{7}{8}$ in. below the top of the upper longerons, in the pilot's cock-pit, should bisect the sides of the tail. This line will be referred to as the line of flight of the machine. That is, it is a line parallel to the path of the machine when the machine is flying level and straight ahead at its rated speed. With the two upper longerons level with each other in the pilot's cock-pit, the rudder post in the tail of the machine should be in a vertical position, and the clips to which the main tail plane, or horizontal stabilizer, as it is called, is fastened, should be level. The motor should be level in the machine, and the center line of the crank shaft of the motor should be parallel with and directly under the center line of the machine. The axle in the landing gear should be at right angles to the center line of the machine, and should extend the same distance out on each side of the fuselage. The clips or hinges to which the wings are fastened must be uniformly located on the sides of the fuselage and in such a position that, when the wings are put on, the upper wing will be 12 in. ahead of the lower one. The center of the center section must be exactly above the center line of the machine."

It would be impossible to mention here all of the details watched by the inspectors as they looked over the fuselage, but a few will be interesting. "Make sure that the controls in the floor of the cock-pit are properly fastened. Be sure that the main stay-rods in the under side of the machine have not been cut by some Hun sympathizer. What is in the fire extinguisher, Pyrene or gasoline? Have all the internal brace wires in the fuselage been fastened so that the vibration of the motor will not loosen them? Are the brace wires that hold the motor in place damaged by corrosion?"

The controls to the motor, and instrument leads from the motor, were carefully examined, but in doing so the inspector knew that the man who tested the motor later on would find out whether every part of the power plant was functioning, so he looked the motor over more to help hasten the work than anything else. However, every defective instrument and damaged motor part was tagged as soon as it was found.

Before the machine could leave the assembly floor its propeller had to be properly installed. Before its installation the propeller was checked up by the following specifications: it must be in static balance, 3 in-oz. being the maximum error. The error in

[1] Recently of the U. S. Air Service.

track and length must not exceed ⅛ in., that is, ± 1/16 in. The error in pitch must not exceed 1 deg. at any point along the effective areas of the two blades, and the average error in pitch of the two blades must not exceed 20 min.

Every propeller was carefully watched for defective workmanship, and the writer has seen a great number of excellently finished oak and walnut blades unerated in France with the hub hole bored through each at such an angle as to give the propeller a track error of half an inch. An Englishman in looking over the propellers said: "I say, why don't you fellows catch the Hun who is boring those holes for you?"

Motor and Propeller Inspection

The motor, of course, received a careful test. It was placed in a concrete stall where a free current of air could be obtained, and a bank of dirt received the bullets from the machine guns when their synchronizing mechanism was tested in connection with the propeller. The following requirements were rigidly demanded of every motor. After being warmed up it must run at 1600 r.p.m. without loading or choking; throttle to at least 300 r.p.m. without stopping; maintain an oil pressure of not over 30 lb. nor under 15 lb. in its range of speed; maintain a speed of 1500 r.p.m. without excessive vibration or over-heating; show that it is getting proper lubrication, that its ignition and throttling mechanisms are in first-class condition; and the sound of its exhaust must indicate that its valve openings are properly adjusted.

After this test a rigid inspection of all water, oil, and gasoline leads must prove that there are no leaks. A second check was made of the propeller alignment and general behavior of all motor control instruments. One instrument which was very carefully watched was the tachometer. It was very necessary to know that the motor actually developed its rated r.p.m., for with a standard propeller the motor speed was a direct check on the horsepower of the motor.

Final Inspection of Machine and Its Instruments

In the final inspection, after the machine was fully rigged and before its flight test, the following alignment specifications were followed. The angle of incidence measured with a straight edge rule and level must be 3 deg. The method of checking this was very simple. A straight edge touching the under side of the rear edge of the rear wing beam and held level must be 1 15/16 in. from the rear edge of the front wing beam when the machine was level in its line of flight. That is, the under side of the wing must cut the air stream at a positive or lifting angle of 3 deg. A simple jig reduced this check to the taking of one measurement, that is, the 1 15/16-in. measurement, with an over- and under-limit of 1/64 in. The dihedral angle of 3 deg. was even more easily checked. A string stretched across the top of the upper wings above the front wing beam must clear the center section 9⅛ in. when it touched the wing at the center strut fittings.

But the details which must be covered on an airplane before it can be OK'd as a perfect machine are an entirely different matter. For instance, to counteract the torque of the 400-hp. motor an extra amount of incidence must be put in the left wing. If this were not done the big bird would fly as though it had lost some of the feathers from its left wing. If the inter-plane struts are not all of proper length, the upper wing will not have the same angle of incidence as the lower one, and the pilot will say that the machine is heavy on one side, that it does not want to climb, or that it has a heavy tail. The angle of incidence is the all important factor in the final alignment of an airplane.

Then new wire, or cable, as it is referred to, will always stretch. The question of just how tight the machine can be set up and not endanger the strength of its own members and at the same time be sure of holding its alignment is one that the inspector must be able to answer without a second thought. With the check-up on equipment, and especially such special equipment as cameras, bomb-dropping sights, and machine guns, comes the necessity for an inspector with a ready mind. If he is not wide awake he will surely pass his machine with some of its vital parts missing.

The compass must be adjusted after all other apparatus has been installed. The residual magnetism of the motor has a tendency to throw the magnetic needle out of its proper course. When the motor is running, the magnetism of its rotating parts produces a still heavier effect on the compass needle. Before that instrument will function, the magnetic effect of the running motor must be counteracted. The inspector must make sure that the compass needle will point straight north when the machine is in the air, and he must, if possible, get all adjusting done before the flight test.

On the field the machine underwent a hasty inspection by the test pilot before flight. In the air it must fly level with a motor speed of 1350 to 1400 r.p.m. It must be easy enough on the controls to permit the pilot to release the stick and maintain his course and altitude with the use of his rudder alone. The motor must meet all the demands before mentioned, and in addition be able to maintain its r.p.m. in a steep climb. That is, a change of the level of gasoline in the float chamber of the carbureter must not affect the motor speed.

The card system mentioned earlier in this paper was a great aid in getting the excellent results obtained by the inspection department. When the assembly work was begun on the machine a card 5 in. by 8 in. was put in a holder on the outside of the machine. As one part of the work was completed or one alignment properly checked out the inspector on the job made record of the fact on the card. At the same time if he found some defect which must be remedied before the final OK he noted it on the back of the card. When the machine was ready to leave the first department all the assembly work assigned to that one floor had been passed on by the inspector and many of the defects remedied, which might have been overlooked later on, or if discovered would have delayed the machine in its schedule. The inspector who passed the machine to the next department removed the card and put on one which, it might be said, gave it the privilege of leaving the first assembly floor. Any defects still unattended to were carried forward to the new card and the old card was filed in the inspector's office as a part of the history of that plane. This process was repeated four different times, the plane receiving at last a final OK from the inspector. This OK was on a linen tag and remained on the machine when it was delivered to the front. If at any time a defect was found that would hold the machine in the department as much as two hours over its schedule, the inspector would remove the regular inspection card and put on a repair shop card which constituted a pass to the repair shop for that machine. When the repair shop card was properly signed, by the inspectors at the repair shop, the machine was placed back into the assembly process again and its old card was attached to it.

Personnel of Organization

A careful selection of the men available for inspection work revealed the fact that young men with some college training or at least high school education made the best inspectors. Men skilled in automobile repair work were the poorest. They wanted to do the job themselves. Jewelers were available for instrument inspection and cabinet makers for wood work. But men who could and would learn how to exercise good judgment along mechanical lines were hard to find. The best inspectors it was found could be more easily and quickly made out of young men who had not had a large amount of practical mechanical experience along any line.

The organization, which in November was capable of passing successfully on 50 complete airplanes a day, consisted of 75 non-commissioned officers and privates, and 10 commissioned officers. Five of the commissioned officers were test pilots. There were five distinct departments, first inspection, fuselage assembly inspection, motor inspection, final assembly inspection, and flight test. The daily and hourly reports came on the regular inspection cards to the inspection office from these different departments. The record of the work of the department is best told by saying that none of the 1400 machines passed by that organization, up to November 11, 1918, failed on the field because of some defect carelessly overlooked by an inspector.

INDUSTRIAL DEVELOPMENT IN THE TRANS-MISSOURI REGION

By P. F. WALKER,[1] LAWRENCE, KAN.

By the Trans-Missouri region is meant the section of country west of the chain of towns on and in prolongation of the Missouri River, the prolongation referring to that part of the river north of Kansas City and extending westward into the intermountain region until the point is reached where Pacific coast shipping conditions are directly felt. This forms one of the zones recognized by the Interstate Commerce Commission in its railway-rate regulation measures. It is not the plan to include the whole of this zone, however, because vital factors other than railway rates tend to limit us in north and south directions, notably the influence of fuel supply. Our region then includes the entire states of Kansas, Oklahoma and Colorado, and parts of Texas, Arkansas, Missouri, Nebraska, and New Mexico. Gulf conditions cut off a considerable portion of Texas, as do Mississippi River conditions portions of Missouri and Arkansas. A strip of southern Nebraska and the northeastern portion of New Mexico come in to round out the circle of influence exercised by the oil field. It is worth noting that the geographical center of the United States lies due north of the center of this region and within the state of Kansas. It is, therefore, a section cut out of the heart of the country.

It is well to consider with care the natural resources of this region other than oil and gas. They are of significance on several bases: first, as raw or auxiliary material consumed in the production of finished goods; second, as indicative of the capacity of the region to support population in the direct matter of foodstuffs; and third, as an index of freight traffic on the railroads, and thus of the importance of the region in the transportation business of the country. The following figures are about ten years old and so are not to be taken to show accurate values for today, but are relative and so indicative of conditions in this group of states when compared with the United States as a whole. The figures are totaled for the states of Nebraska, Kansas, Oklahoma, Texas, Colorado, and New Mexico when available. It is to be borne in mind that the population of these states amounts to about 18.5 per cent of that of the United States and also that the center of population of the country has been moving westward gradually until now it is Indiana. This last point is of significance in the transportation of foodstuffs as well as in the location of the domestic market for manufactured goods.

Agricultural

Only approximate statements are given. In staple foodstuffs, wheat and meat products, the region produces about 40 per cent of the total for the country. This being four times the population ratio, three-fourths of the total product moves outside the region in either raw or manufactured form, representing an immense amount of through freight originating here. Other foodstuffs are more nearly balanced as regards shipment into or out of the region, with a difference in favor of the incoming in many of the more expensive varieties. In cotton and other fiber products the movement is outward, but not in notably large quantity. In general, the producing power of the region is far in excess of its population needs and creates outgoing traffic. It means a balance of credit in its favor, a not inconsiderable portion of the capital thus represented being invested in projects outside the

Mineral Products

The total value of the output of mines and quarries in this region amounted in 1909 to $123,214,000, which is 9.95 per cent of the total for the United States. This figure includes lead and zinc for Missouri because of the fact that in recent years this industry has moved almost wholly into Oklahoma and Kansas, and always has been identified in a distinctive way with these states. These mineral products are of special significance. It is to be noted that the percentage is essentially the same as that of population. Developments of recent years have made it slightly more. Outside of petroleum products, the most distinctive are lead and zinc, occurring and treated as one. The figures of ten years ago show this item as $23,196,000, 81.2 per cent of the total of the country. The figures are altered now, but possibly the older ones are fully as significant as are those resulting from the abnormal conditions of the last two years. The deposits are small in area, but of tremendous significance in the production of those metals on a world basis. Happening to occur at the junction of three states, the really small distribution appears in a large way in the published statistics. In this case concentration is a fortunate circumstance, especially as the field is close to the best coal and petroleum fields of the region.

Coal deposits occur in workable form in each state excepting Nebraska. The total product is about 27,000,000 tons, which is 7.1 per cent of the total of the country. The wide distribution is a fortunate element with reference to the general upbuilding of industrial enterprises, and an increased production would follow with the increasing demand. The western mines have been proven to produce coal yielding fair grades of metallurgical coke, a thing, by the way, which should be followed out and developed with care. Its association with the foundry and machine products business is apparent.

Gypsum is produced in nearly every part of the region, the total output amounting to $1,381,300, which is 23.8 per cent of the total of the country. This output can be readily increased and to advantage.

Limestone is abundant throughout and is produced as desired. The recorded output is 7.5 per cent of the total of the country and valued at $2,237,000. This is independent of that produced directly for cement manufacturing purposes.

Clays, shales, and limestones for the production of many varieties of clay products, including Portland cement, are abundant. Monetary or quantitative values are difficult to secure, and as records, would be of slight significance. There is no limit at all to possible developments in this line dependent upon quantities of material available. Cement manufactures are included in manufacturing statistics to be discussed later.

In the western portion of the region many of the finer metals are plentiful, notably copper, silver, and tungsten. They do not figure appreciably in respect to transportation considerations, however, and their development is dependent on conditions quite special and distinct from other economic relationships.

In general, the outstanding resources of the region which contribute to the enterprises of the country as a whole beyond the needs of the local population are the cereals and meat products in the food group; lead and zinc spelter and gypsum products in the metal group, together with the special rare metals of Colorado; salt in both raw and refined forms; and petroleum and its refined products in the fuel group. In large measure these commodities leave the region in raw or only partially manufactured form. Others of the list of resources are undeveloped because of the fact that their shipment in raw material form is impossible, and manufacturing enterprise has not yet brought the opportunity for full realization of the possibilities.

Accomplishments in Manufacturing

Only a brief summary will be given. Contrary to the popular impression, the number of kinds of manufacturing enterprises which have grown up in the region to an extent which makes them of real significance in supplying the markets is large, and to go into detail is beyond the scope of this paper.

In 1909 the value of the manufactured products in the six states was $988,642,000. This is 4.8 per cent of the total for the United States. Some advance has been made in the past ten years, although the percentage relationship may not be greatly increased because of the tremendous impetus which manufacturing has undergone everywhere. If we eliminate the meat-packing plants of Kansas City and Omaha, in order to get a closer comparison with respect to general diversified manufacturing, the percentage

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drops to 3.6, or almost exactly one-third the amount which the local market demands on the basis of population. After making due allowance for manufactured goods going to export trade, it appears that our region is producing, in gross, slightly over 40 per cent of the value of articles needed in local markets. Probably the surprise is that the percentage is so high rather than so low, although it is to be borne in mind that the purchasing power of this western region is high compared with many blocks of population of similar size in the congested cities of the east, so that our actual market is not supplied up to this figure.

The lines of manufacturing in which a substantial development has taken place, arranged without reference to magnitude, are as follows:

Meat packing	$310,742,000
Flour and grist-mill products	146,271,000
Canning and preserving	2,793,000
Dairy products	17,902,000
Cotton goods	2,815,000
Men's clothing	3,933,000
Leather goods	8,746,000
Medicines and druggists' preparations	2,636,000
Tobacco goods	2,877,000
Lumber and timber products	48,252,000
Clay products (not including cement)	1,411,000
Portland cement	5,537,000
Glass	2,037,000
Salt, refined	1,513,000
Agricultural implements	521,000
Foundry and machine-shop products	24,807,000
Furniture and refrigerators	2,670,000
Sheet-metal manufactures	4,608,000
Paint and varnish	1,948,000
Wall plaster (gypsum)	884,000
Paper and paper goods	300,000
Railroad shop-repair work	39,706,000
Zinc smelting	13,859,000
Oil refining	......
Beet-sugar industry	......
Total	$646,768,000

Certain industries included in census reports under the heading of manufactures, such as printing and publishing, artificial ice, bakery products, etc., which are in themselves considerable items, are omitted from the list because they bear a somewhat different relationship to industrial development than do the others, which are forced to go to the market on a purely competitive basis. These listed industries, with values subject to great changes during the past ten years, but taken as they stand, involve the operation of equipment calling for 437,623 hp. They represent an invested capital of $310,255,000 and the employment of 135,044 persons.

It is significant that these enterprises are well distributed over the region, and that they embrace the nucleus of a mill population. This does not mean a mill population of the type found in manufacturing cities of the East, but it does mean that there is a group that is becoming skilled in shop and factory work. It is well known that the development of a population with a portion sufficiently large that is trained and acclimated to industrial-plant activities, so as to make the systematic development of manufactures possible, is a long process. Happily the progress made already in this region has carried us through the first difficult stages, and the curve of difficulties grows flatter and cause for concern on this score is rapidly growing less.

Transportation and Freight Adjustments

The one element in industry which must form the basis for gravest consideration in this Trans-Missouri region is that of transportation and freight adjustments. Freight rates make or break enterprises without number. This region has been peculiarly unfortunate during some periods in the past history of railroad manipulations and later adjustments, and anything that is done on a considerable scale very far west of the Missouri River must be prefaced by a very careful study of the rate situation. It is well understood that the river towns are basing points for through shipments and enjoy certain advantages on that account as compared with interior points which have to bear a local-rate addition. It results, therefore, that on commodities to and from the eastern markets the towns away from the river have a handicap that may be considerable, especially if some secondary material like fuel must be transported westward through a river point to the point of manufacture of the article in question.

We have a special interest, however, in the shipping conditions westward, now greater than ever with the striking possibilities before the Pacific coast towns. In the intervening country lies the natural home market for manufactured goods produced in the Trans-Missouri region. With the growth of that section of country should go the growth of industries in this section. The problem has been to reach it with our goods under conditions advantageous with reference to other more distant regions. Previous to the war, before the taking over of the railroads and the confusion resulting from unprecedented demands upon our entire transportation system, two steps had been taken in the adjustment of rates which reacted favorably for this region. The principles laid down in those decisions are practically sure to hold whatever the ultimate destiny of the railroads may be.

By the decision of the Interstate Commerce Commission in 1911, and upheld by decision of the Supreme Court in June, 1914, on traffic originating at the Missouri River and points west thereof, the rates to intermediate points should not be more than the rates through to the Pacific coast terminals. This region is designated as Zone 1. On traffic originating in Zone 2, which is the region east of the Missouri River as far as the Chicago territory, the rates to intermountain points should not exceed by more than 7 per cent the rates through to the coast terminals. Similar provisions with increasing percentages of excess are prescribed for zones in territory still farther east. This decision made the intermountain territory accessible to this Zone 1 region on terms slightly in our favor as compared with shipments made by way of the Pacific coast terminals.

The policy of blanketing the westbound rates over the eastern half of the United States gives another point that is favorable in a slightly more positive sense. By this plan of blanketing, the rate on a shipment westward is the same when starting from any point east of the Missouri River. Traffic originating west of the river for west coast or intermountain points may be given lower rates. This distinctly favors the establishment of enterprises in this district for the intermountain market.

With the opening of the Panama Canal a new condition was created. With the above conditions in force any lowering of rates to coast terminals to meet the new type of competition of the water routes would have carried like reductions to all intermountain points. It was clear that some adjustment was necessary in order to preserve for the railroads an amount of business that would enable them to serve the country. On January 29, 1915, the Interstate Commerce Commission rendered its decision, containing this provision; that from points on the Missouri River and in the territory west thereof carload rates to intermediate points are not to exceed those of Pacific coast terminal points, points are not to exceed those of Pacific coast terminal points, except for a list of twenty-eight articles or commodity groups which consist, for the most part, of various kinds of iron and steel manufactures. The decision also contains the provision that for these excepted articles the rate to intermediate points east of the Missouri the rates to coast terminals may be less than for intermediate points on a much greater number of articles.

Under transportation conditions of the last two years many changes have taken place in rates but the above comparison as to the relative adjustments will remain as the substantial basis, with little question of doubt. That such adjustment constitutes any marked advantage for this Trans-Missouri region in shipping to western markets over eastern producing territory, is not claimed. It does, however, tend to remove the unfavorable conditions which previously existed, and serves to give a fair and

equal opportunity for manufacturers of this region to reach a market which is bound to be increasingly profitable.

Result of Present-Day Transportation Difficulties

A condition, more or less temporary, exists now in the transportation business of the country which in a very real way makes for the encouragement of industrial enterprises in the West. This is the fact that shipments of goods from the East are difficult to secure. Because of the need this has produced the Pacific coast business men have actually started manufacturing enterprises of considerable magnitude. A few years more of the present stringency in transportation facilities and the west coast region will have developed a manufacturing business which it would not have done, under more normal conditions, in as many decades. In only a small measure is the situation different in this mid-west region. All that is needed are progressive groups of men, business men and engineers, who are alive to the fact that permanent prosperity and the unchecked increase in the value of their securities depend upon the development of a well-rounded out group of producing industries, and who in their several communities will devote their influence and energies to the encouragement of prospective manufacturers. This transportation tie-up is not a simple matter of diversion of effort to moving war material nor an illustration of inefficient management. Serious as may have been these factors, there is another that is with us to stay. It is the greatly augmented foreign trade that is upon us as a nation and that is bound to be a dominating factor in many phases of our industrial life. All over the country there is being preached the doctrine of promotion of export trade, and it means a change in many of our practices and ideals. An opportunity is at the door of this country greater in its way than anything else that has come to us in history. In a dozen different corners of the globe there are markets waiting for intelligent development by this nation.

The export trade in manufactured commodities may be a matter somewhat remote from this section west of the Missouri River so far as direct participation in it goes, excepting for products in the lines of foodstuffs, petroleum, lead and zinc. Even in those lines, in which production is on such a large scale, it may be that a wiser course to pursue is to look a little less intently for the foreign market as a direct market, and give more attention to the development of the varied lines which will build up our own region and make the home markets a more complete absorbent for these dominating products. And in particular let it be observed that the diversion of so much product from the established manufacturing centers, from home to foreign markets, makes the creation of new industries in these regions more natural. Materials in place of manufactured goods in return for the immense quantities of freight taken out of the region in the form of cereal and meat products only partially manufactured will mean the development of our population in more systematic manner, and the substitution of intensive for extensive method on many wide expanses of the western plains. It will mean a more complete realization of the possibilities which lie in these sections of Texas, Oklahoma, and western Kansas which now yield so little.

Regional Fuel Situation

There is one serious condition which remains to be satisfied in the full before such program can be carried out in full confidence. Reference more or less detailed has been made in four of the prime essentials for industrial development; namely, materials, labor, transportation, and markets. A factor of equal import is that of power, which means the regional fuel supply. Coal is well distributed over the region, but the deposits are not large. The Pacific coast states have at their north doors in the remarkable coal deposits of Alaska, a source of energy for industrial enterprises that is unmeasurable. All that is needed is a more enlightened policy on the part of the federal administration to make coal production from that field a sure and determining factor in our national progress. Before we are many years older Alaskan coal will be on its way in American ships through the Panama Canal up the Mississippi River for distribution in the Missouri Valley. But the Pacific coast states will have that coal first, and at low cost.

The fuel situation in this Trans-Missouri region calls for careful survey and analysis. The extent to which the unique petroleum resources will be available for local industry should be worked out by men who have the oil business at their fingers' ends. The full realization of possibilities in the lead and zinc field is waiting on the creation of a source of cheap power, making the electrolytic-zinc process feasible. The full utilization of paper pulp in the arts, with untold tons of the principal raw material going up in smoke on the Kansas wheat fields while the forests of the north are dwindling, is dependent upon the economical production of heat energy in the form of steam. The time is not far distant when fertilization of western soil will be demanded, for which nitrogen secured by the fixation process of electrical means is the direct response. It is the fuel that is to determine the future of the region and this Section of the Society can do no greater service to the people of the country than to produce the sound facts which will show where we stand. This can be done by well considered information which will show material facts regarding both petroleum and coal as the fuel supply on which the local industrial life of the region must depend for indefinite periods of time.

A VOLUMETRIC EFFICIENCY TEST OF A VACUUM PUMP

By GEORGE S. TAYMAN,[1] TULSA, OKLA.

It was the purpose of this test to determine the volumetric efficiency and indicated horsepower of a Laidlaw-Dunn-Gordon Duplex dry vacuum pump, size 18 in. by 12 in., when operating under different intake and discharge pressures. Tests were made on April 10, 1919, at Station No. 28, Helen Hardridge Lease, for the Gypsy Oil Company, located at Tulsa, Okla.

The vacuum pump was belt-driven by a 2-cycle Bessemer gas engine rated 50 hp. at 180 r.p.m., and a 11 in. by 12 in. Ingersoll-Rand duplex booster was used to obtain a vacuum on the discharge side. The booster was also driven by a 2-cycle Bessemer gas engine, rated 50 hp. at 180 r.p.m.

The general arrangement of piping and connections for gages, orifice prover, and location of thermometer wells were as follows: The intake of the vacuum pump consisted of a 6-in. line with gate-valve near the pump for controlling the vacuum on the intake. Connections for manometer and thermometer wells were located between the gate-valve and vacuum pump.

The discharged air was led to a scrubber tank in order to eliminate the effect of the pulsations from the pump to the manometer, the latter being placed in the discharge line near the vacuum pump. The intake of the booster was connected to the scrubber tank, and the degree of vacuum or pressure on the discharge side of the vacuum pump was controlled by a gate-valve on the intake of the booster. The discharge line from the booster was connected to a second scrubber tank, and the orifice prover was connected to this tank by a 4-in. pipe. The function of this scrubber tank was to maintain a uniform pressure on the orifice prover during each test by reducing the pulsations from the discharge of the booster as far as possible.

Before starting the test the valves were removed from the vacuum and thoroughly cleaned and inspected. The packing glands were tightened on the piston rods of both vacuum pump and booster and tests were made for air leaks on all manometer connections. The intake valve of the vacuum pump was set so as to obtain a vacuum of 28 in. of mercury, and the intake valve on the booster was left wide open (this being the controling valve for discharge vacuum or pressure on vacuum pump) and under such conditions a maximum discharge of 24 in. of mercury was obtained.

It should be noted that the displacement of the booster per revolution was less than that of the vacuum pump, and that it was also driven at a lower speed, therefore, a high vacuum during

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the discharge period of the vacuum pump could not be expected. When a vacuum of 20 in. of mercury was obtained during the intake of the vacuum pump, the booster had only sufficient capacity to reduces the discharge pressure to atmospheric. The intake vacuum was kept constant for each series of tests and the

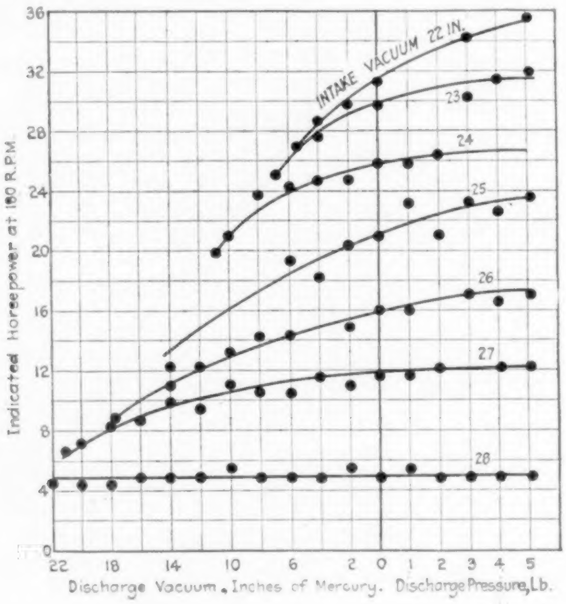

Fig. 1 Indicated Horsepower Curves of an 18 x 12 in. Laidlaw-Dunn-Gordon Pump

discharge vacuum varied from the highest value that it was possible to obtain by the use of the booster to the greatest discharge pressures.

The following observations were taken for each test. Temperature of intake, temperature at orifice prover, vacuum on intake

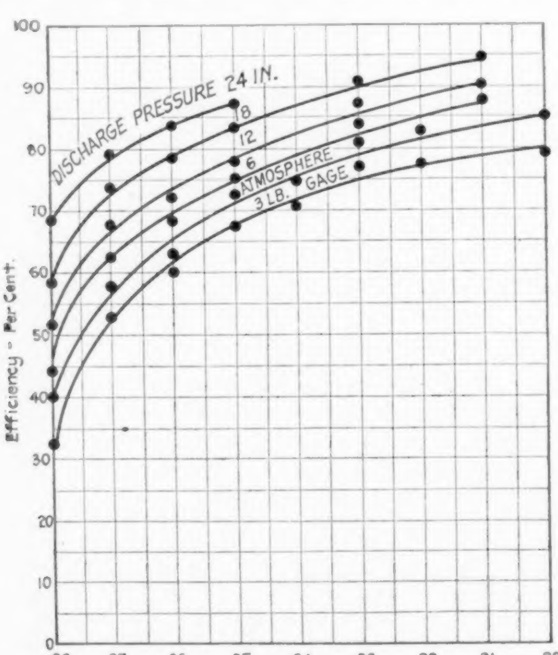

Fig. 2 Volumetric Efficiency Curves of an 18 x 12 in. Laidlaw-Dunn-Gordon Pump

(constant for each series of tests), vacuum or pressure on discharge of vacuum pump, volume of air discharged through orifice prover per hour, barometer reading, and r.p.m. of vacuum pump.

Three indicator cards were also taken for each test; one from each end of the cylinder and one including both ends. An American-Thompson indicator with 16-lb. spring was used for this purpose. From the cards thus secured the indicated horse-power was calculated, and curves plotted of indicated horse-power as the discharge vacuum or pressure, one curve being plotted for each intake vacuum from 22 to 28 in. inclusive, as shown in Fig. 1.

The primary object of this test, however, as previously stated, was to obtain a set of volumetric efficiency curves for constant discharge pressures with variable intake vacuum. Accordingly from the data secured, curves were plotted of volumetric efficiency vs. intake vacuums, one curve being plotted for each intake vacuum from 20 in. to 28 in. inclusive as shown by Fig. 2. The volumetric efficiency, in each case, was calculated by the following equation:

$$E_v = \frac{AT\sqrt{\frac{P}{P_1}}\left[\left(\frac{P}{13.6}\right)+B\right]}{DT_1\ P_2\ N}$$

When

E_v = volumetric efficiency
A = cu. ft. of air per min. through prover as shown by open holes
P = pressure on prover in inches of water
P_1 = correct pressure of orifice prover from tables
P_2 = absolute pressure on intake of vacuum pump in inches of mercury
B = barometer reading at time of test
T = absolute temperature of intake
T_1 = absolute temperature at orifice prover
D = displacement of vacuum pump, cu. ft. per revolution
N = revolutions per minute of vacuum pump.

Engineers in the Pan-American Financial Conference

Those in charge of the Second Pan-American Financial Conference state that the engineering profession will be well represented at the January conference to be held in Washington. Latin-American engineers are more closely connected with important industrial projects and have a greater command in matters pertaining to the developments on which they are working than is the case in the United States. Our own engineering profession may, therefore, do well to study the Latin-American plan of coöperation between capital and the engineers. The former Assistant Director of the Bureau of Foreign and Domestic Commerce has gone to Central America to obtain definite data on the credit and investment requirements of Latin-America, and these data are for the special use of the conference.

Experimental Work on Oil Shales

Because of the enormous amount of oil tied up in the great shale deposits of the United States it has been the opinion of many engineers that the recovery of the oil can be profitably undertaken. A bill has been introduced in the Senate proposing to provide the Bureau of Mines with $140,000 for experimental work on oil shales. The Secretary of the Interior has advised the Senate Committee on Mines and Mining that the plan for the proposed research work is necessary to ascertain the most profitable way of recovering the oil. The bill has his complete approval.

A large initial outlay of capital will be necessary in any projects organized to get commercial oil in this way because an extensive manufacturing process is involved. The importance of accurate and extensive preliminary research work is, therefore, apparent. This source of petroleum supply will be of added value to the country when the point is reached where oil wells do not produce sufficiently to meet all requirements. One item of great importance which must be looked to in the future is the increasing tendency to use oil in high-power naval craft.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A. S. M. E.

Industrial Research

IN an excellent paper on Industrial Research by Dr. Frank B. Jewett, read before the Royal Canadian Institute at Toronto on September 8, 1918, the great need for the training of research men is again clearly set forth, and the method of obtaining these men for this work is outlined. The concluding remarks of this paper are very significant, and are given here for the consideration of our members:

In conclusion I should like to present for your consideration a few points which I think are fundamental to the successful carrying out of any broad policy of industrial research growth within a nation and a few other points which my experience has taught me to look upon as beacons in the course of building up an effective and smooth-running industrial research organization. The points of the general problem which I would make are:

1 That no extensive and successful industrial research growth can be looked for unless provision is made for a continuous supply of competent men of broad general training and a specific and thorough training in the methods of scientific research.

2 That coincident with the growth of real industrial research there must be a corresponding and equal growth and development in the domain of fundamental scientific research which will broaden the bounds of knowledge and open up new avenues for the industrial research worker.

3 That there must be education to develop a full understanding of the material and economic advantages which will result from the supplanting of the purely cut-and-dry inventive type of growth by the application of scientific research methods and the further knowledge that a vigorous and healthy growth of fundamental scientific research is an integral and absolutely necessary part of the problem. In the one case this education must be directed toward the industrial interests for the purpose of indicating to them the advantages to be gained by an abandonment of methods which are not in accord with the present-day state of world-knowledge and the building up of a demand for the right type of men, and in the other case toward the population at large for the purpose of instilling an appreciation of the advantages which will accrue to the nation and attracting to the field of research, whether fundamental or industrial, a large proportion of qualified men; also for the purpose of having the people at large view with sympathy a reasonable allotment of general funds for the advancement of research activities.

4 That a realization of all of the foregoing can best be obtained by a close coöperation between the industrial and business interests of the country and the higher educational institutions, which are already looked upon with favor by educated and thinking people, and from which must come the men qualified to build up industrial research.

5 That whatever the scheme finally adopted to provide for an expansion in the domain of fundamental research and the development of competent industrial research workers, care must be taken to insure that pressure from the industries will never be so great as to withdraw those men who can render the greatest service by continuing as investigators in the field of pure research and the training of younger men. Such a course would be suicidal if long continued and I mention the point because of the fact that my experience indicates a considerable tendency on the part of industries which have benefited from industrial research to endeavor to attract into their service the best of the university research men. I confess that the temptation to do this is very great and that the monetary inducements which industry can offer to the individual are large and not easily to be withstood by a man whose normal human reaction is for the material welfare of his family.

Finally, as to those specific points which may be of interest to anyone endeavoring to build up an industrial organization:

1 The research department must be so organized, developed, and equipped with men and machinery that the net result, direct or indirect, will be of decided monetary value to the industry. Otherwise, it has no reason to be.

2 The present state of the art is such that a large number of the problems falling within the field of the industrial research laboratory are inherently expensive. For this reason, while enormous returns may be possible from the successful completion of any line of research, lack of success or an attempt to conduct it with inefficient help will mean the waste of much valuable time and money. For these reasons the choice of the staff and the careful consideration of all of the factors in any problem are of the utmost importance.

3 That successful industrial research under modern conditions is essentially one of organization and group working, as distinguished from the essentially individualistic work of fundamental research. For this reason extreme care must be taken to secure competent executives either from the ranks of those whose primary training has been along research lines and who have shown capacity for handling men and complicated problems, or from those of executive capacity and experience who have shown a proper sympathy for the requirements of research.

4 That all industry tends to be conservative and that great care must be taken not to attempt the forced growth of a broad industrial research development where a too rapid growth will engender the active opposition of those who have been educated in a different environment. My experience has indicated that there is never any trouble where the proper method is employed but that there is always trouble if the so-called practical man feels that the proposed new methods are essentially a reflection on his ability and that his point of view is not receiving sufficient consideration. As a matter of fact, the practical man's point of view and his knowledge, gained by long experience, will be found to be one of the chief assets of the successful industrial research worker.

5 That some industries are much more conservative in their attitude toward the adoption of modern research methods than others. In general, I think it will be found that the most conservative are the oldest and are those industries which existed long before the science of their art had been developed. Because of the fact that modern electrical and chemical industries have grown directly from pure scientific developments, I think they will be found to be easier fields for the cultivation of industrial research than older industries, such as those which were well developed in the earlier periods of human affairs.

6 Finally, a most important point, not to be lost sight of in the organization of a successful industrial research department, is the fact that many very capable men trained for industrial research are essentially devoid of certain commercial attributes. Many of them, for instance, fail to realize that on a large number of their problems time is an essential element in the work, while others fail to give due weight to that phase of the work which lies between the completion of the research activity and the introduction of the results into commercial manufacture or employment under modern conditions where the day-by-day control must, of necessity, be largely in the hands of those who are not highly-trained skilled workers. For this reason it is essential that whoever is responsible for the direction and success of the industrial research under-taking should be a man with a broad outlook, a full appreciation of all of the factors of the business problem and a man who can sympathize with and appreciate the varying points of view which he encounters and who can harmonize all of the activities into a smooth-working machine.

In closing, I wish merely to go on record with you by saying that after many years of experience, I now, as an executive in a large technical organization, am more than ever a firm believer in the benefits to be derived from a vigorous stimulation of both fundamental and industrial research, benefits which I believe will accrue not only to individual industries but to the people at large as well. It seems to me that, provided we have proper legislation to safeguard a just distribution of the benefits, we have in industrial research a most valuable means for ameliorating and bettering the conditions of mankind.

United States Bureau of Mines

The Bureau of Mines of the Department of the Interior has been recently reorganized under general order dated August 1, 1919. This general order describes the relation between the various branches of the Bureau and the duties and responsibilities of the various officers and employees of the Bureau. To give a brief statement of the plan of organization, the following statement and table have been taken from this general order:

The work entrusted to the Bureau involves matters both of business and of investigation. This necessitates that there shall be both administrative and technical control. In some matters there is necessity for only the minimum of technical control, since the work is either non-technical in character or follows established routine. In matters primarily investigative, it is desirable that the minimum of non-technical administrative control be exercised. For this reason the investigative work is set off as much as possible from the other work of the Bureau. The Bureau will, therefore, be organized with Investigations and Operations Branches with suitable subordinate divisions and sections, and so far as possible, work and personnel

will be assigned to one or the other. It will be necessary in certain instances that the work be co-operative as between sections, divisions, or branches, or that a member of the Bureau may work for a period or regularly for part time with more than one section or division. In all cases the officers of the Bureau are charged with the duty of marking out a clear line of responsibility in regard both to administration and technical control, subject to the authority and final approval of the Director. Allotments and transfers of funds will be made for the various divisions of the work only on authority of the Director.

The general plan of organization will, therefore, be as follows:

UNITED STATES BUREAU OF MINES
DIRECTOR

Investigations Branch Assistant Director	Operations Branch Assistant to the Director
1 Division of Mineral Technology	1 Office Administration
2 Division of Fuels	2 Division of Education and Information
3 Division of Mining	3 Government Fuel Yard
4 Division of Petroleum and Natural Gas	4 Mine Rescue Cars and Stations
5 Division of Experiment Stations:	
Pittsburgh, Golden	
Urbana, Salt Lake City	
Columbus, Tucson	
Bartlesville, Seattle	
Minneapolis, Berkeley	
Fairbanks	

In connection with this attention should be called to the dedication of the new million dollar laboratories comprising the Bureau of Mines Experiment Station at Pittsburgh, Pa., in which the Pittsburgh Chamber of Commerce coöperates. The exercises will extend through three days, from September 29 to October 1.

Arthur M. Greene, Jr.,
Chairman of Research Committee.

A—Research Results

The purpose of this Section of Engineering Research is to state the source of research information which has been completed, to give a resume of research results with formulae or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigator do not warrant a paper.

Aircraft A1-19 Wind Tunnel Investigations. The wind tunnel at the Bureau of Standards has been used for studies in connection with fall of aircraft bombs in rapidly moving air steams, and the effect on the position of the center pressure by displacement of the stabilizing finns forward and backward. Studies are being made on the manner of damping aircraft bombs which oscillate and of bringing them back to steady flight. Tests have been made on the aerodynamical characteristics of a model flying boat. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Aircraft A2-19 Angle-of-Attack Meter. Calibrations of pressure head used with angle-of-attack meter up to speeds of 120 miles an hour, Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Aircraft A3-19 Beams. Three-piece beams as strong as solid beam. Technical Notes, Feb. 15, 1919. Forest Products Laboratory, Madison, Wis. Address Director.

Automotive Vehicles & Equipment A1-19 Exhaust Gases. Vitiation of Garage Air by Automobile Exhaust Gases, by G. A. Burrell and A. W. Gauger. Technical Paper 216, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Concentration of Ores A1-19 Manganese Ore. Problems Involved in the Concentration and Utilization of Domestic Low-Grade Manganese Ore by Edmund Newton, War Minerals Investigations Series No. 9. Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Concentration of Ores A2-19 Sulphur Ores. Concentration of Native Sulphur Ores by Flotation by James M. Hyde. Minerals Investigations Series No. 15, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Fuels, Gas, Tar & Coke A4-19 Coal Analysis. A Method of Least Squares Applied to Estimating Errors in Coal Analysis by J. D. Davis and J. G. Fairchild, Technical Paper, 171, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Fuels, Gas, Tar & Coke A5-19 Lignite. Combustion Experiments with North Dakota Lignite by Henry Kreisinger, C. E. Augustine and W. C. Harpster, Technical Paper 207, Bureau of Mines, Address, Van H. Manning, Director, Washington, D. C.

Heat A2-19 Solder of Intermediate Melting Point. In aircraft research work a solder melting at about 400 deg. cent. was needed. One of the following composition was found to be satisfactory: Silver 40 per cent, Tin 40 per cent, Copper 14 per cent, Zinc 6 per cent. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Leather & Glue A2-19 Comparison of Various Types of Glues. The Forest Products Laboratory of the United States Department of Agriculture at Madison, Wis., has issued a circular on the comparison of various kinds of glues: animal, casein, vegetable, blood and liquid. Animal glue has been used for a long time. It has great strength, a free flowing consistency and does not stain fancy veneers. Its price and the fact that it does not resist water to a high degree are the factors which limit its use.

Casein glue is made from casein obtained from milk. It has been used for a short time commercially and its possibilities and limitations are not well known. It can be spread with a brush when cold and has a good strength. Its special value lies in its high resistance to water. This glue stains through veneers. When hard it is difficult to machine.

Vegetable glues are made from starch and are quite cheap. They are used cold and remain in a good working condition for many days. They are very viscous and are difficult to spread by hand. They lack resistance to water.

Blood albumin glue is made of soluble dried blood and is of high water resistance. The formula for mixing may be changed to produce various properties. The great objection to the use of this glue is the expense of the apparatus required.

Liquid glues are usually made of skin and bones of fish or animals quite similar to animal glue. They are ready for immediate use, have little or no water resistance and the cost is high.

Leather & Glue A3-19 Animal Glues. The Forest Products Laboratory of the United States Agricultural Department at Madison, Wis., has issued a circular on animal glues, their manufacture, preparation and application. The stock of bone and skin is washed and treated to remove dirt and grease and then boiled to extract the glue forming substance. The solution is concentrated by evaporation until jelly forms on cooling. The jelly is cut into various forms and dried. Calcium salts are removed for higher quality of glue. Temperature and time are controlled as overcooking reduces strength. Stock may be boiled several times to obtain glue solution. Mineral matters such as barium sulphate, white lead, zinc oxide or whiting may be added to the concentrated solution before cooling to give color and make the glue opaque.

Nominal grades can be relied upon for high-grade work. It is necessary to specify requirements and then provide means to determine whether or not those requirements are fulfilled. A system of classification based on jelly strength was devised by Peter Cooper. These are designated A Extra, 1 Extra, 1, IX, 1¼, 1⅜, 1½, 1⅝, 1¾, 1⅞, 2. 1 Extra is the strongest glue. There are now glues stronger then 1 Extra and weaker than 2. This is little used today.

In using glues it is important to find the proper proportion of glue and water for the best results with the wood used and the conditions under which it is used. This should be determined by strength tests and then the proportion adhered to. Clean cold water should be used and the mixture thor-

oughly stirred to prevent lumps, allowing it to stand in a cool place until the glue is thoroughly water soaked and softened. This may take from one hour to ten hours. It should then be melted on a water bath of not more than 150 deg. fahr. as high temperature and long heating reduces strength. The pot should be kept covered to prevent the formation of skin or scum. The glue should be applied in a warm room free from drafts, and it is good practice to warm the wood without warping it before applying the glue. Clamps should be applied as quickly as consistent with good workmanship.

Clamping pressure should be evenly distributed over joints. The proper amount of pressure is not definitely known. In gluing veneers pressures as high as 150 lb. per sq. in. are sometimes used. Too much pressure may force glue completely from joint.

Strict cleanliness of pots, apparatus, floors and tables should be observed. Old glue becomes foul and breeds bacteria which decompose glue. Glue pots and brushes should be washed after every day's work. Keep brushes in weak solution of carbolic acid. Mix enough glue for one day's run only.

A strength of animal glue is greater than the wood upon which they are used. Certified glues give a shearing strength of from 2200 to 2400 lb. per sq. in. Address Director, Forest Products Laboratory, Madison, Wis.

Leather & Glue A4-19 Blood Albumin Glues, Their Manufacture, Preparation and Application. The Forest Products Laboratory of the United States Department of Agriculture of Madison, Wis., has prepared a circular on blood albumin glues. The use of blood albumin glue is comparatively new in this country. Previous to the entrance into war some plants had their own secret formulae. The demand for water resistant plywood caused increase in production of all kinds of water proof glue. The Forest Products Laboratory developed several formulae for blood albumin glues, and worked out method of gluing thin veneers with such. Prepared blood albumin glues are not offered on the market. Owing to decrease of solubility of albumin with age they are mixed at time of using. The glue is made from fresh blood of slaughtered animals or from black soluble blood albumin obtained by processing fresh blood. Unless fresh blood is utilized at once it must be treated with preservative or converted into dry soluble form by removing the fibrin and part of the red corpuscles and then evaporating to dryness at a temperature below the coagulating point of albumin which is 160 deg. The glue is prepared by the Forest Products Laboratory method according to the formula for which a patent has been applied for in the name of S. B. Henning. The dried albumin is allowed to soak for some time before stirring. The water added should be at room temperature and the soaking should take two hours. It is then agitated until it is of uniform consistency. If any of the material is insoluble the mixture should be strained through a thirty mesh sieve. This mixture makes a glue of considerable value but it is improved by adding ammonium hydroxide and hydrated lime. The formula for which the patent has been applied for is as follows:

Six parts of black soluble blood albumin, 90 per cent solubility. Eleven parts of water at about 80 deg. fahr. One-fourth part of ammonium hydroxide of specific gravity 0.90. One-eighth part of hydrated lime.

After the blood has been put in solution the ammonia is added while slowly stirring the mixture. Lime is then added in the form of a thick cream while slowly stirring. Care should be exercised in adding the lime as a small excess will cause the mixture to thicken. The glue should be of moderate consistency when mixed and should be suitable for use for several hours. The exact proportions of albumin and water may be varied to produce a glue of greater or less consistency.

The glue is applied with a bristle brush or glue spreader. The spreader should only be operated when actually coating the wood as its operation is apt to cause the glue to foam.

To set the glue a minimum temperature of 160 deg. fahr. is necessary. When thoroughly coagulated the glue cannot again be dissolved in water. Heat is conveniently applied by pressing between hot platens of hydraulic press. High temperatures to speed production are apt to cause steam pockets. A pressure of 50 to 100 lb. per sq. in. is desirable. With temperatures of 212 deg. three minutes are sufficient for three ply panel of 1/16 in. plies.

Blood glue is highly water resistant, retaining 50 to 75 per cent of dry strength after soaking or boiling.

Precautions: Weigh out constituents. Add cold water and do not heat. Do not stir until after soaking. Avoid stirring or agitation. Apply pressure before coagulation takes place. Be careful not to use excessive amount of lime. Do not use excessive temperatures. Address Director, Forest Products Laboratory, Madison, Wis.

Leather & Glue A5-19 Dry Glue Process for Thin Veneer. The Forest Products Laboratory of the United States Department of Agriculture at Madison, Wis., has issued a circular on blood albumin glues in which is described a dry glue process for thin veneers of 1/30 in. to 1/125 in. thickness. The previous troubles with thin veneers have been to prevent warping due to the water. The Forest Products Laboratory coöperating with the Bureau of Aircraft Production has developed a blood albumin glue which when dried was used successfully to glue thin veneers. A standard glue was mixed and then applied to tissue paper or cloth after which it was dried. The paper or cloth thus treated was placed between thicknesses of veneer which if too dry were sprinkled or sponged before placing in press where the pressure was from 150 to 200 lb. per sq. in. Address Director, Forest Products Laboratory, Madison, Wis.

Leather & Glue A6-19 Casein Glues, Their Manufacture, Preparation and Application. The Forest Products Laboratory of the United States Department of Agriculture at Madison, Wis., has issued a circular on this subject. Casein glues have been used in Europe to a limited extent in bookbinding and cabinet work, but their production on a large scale was unknown. In the United States the use of this glue is more recent, but there has been a more rapid development. This development was due to the great demand for water-proof plywood.

There are two types of casein glues, one in which the components are mixed dry, the other in which the components are added separately during preparation. Those on the market are of the first class.

The principal constituent of casein glue is casein, a product obtained from milk. This is the curd which precipitates when milk sours naturally. Hydrochloric and sulphuric acids and rennet are used to precipitate casein. Casein is produced by the removal of the butter fat by means of a separator, precipitation of the casein, washing to remove acid or other impurities, drying, finally grinding to a powder. To make it desirable for glue it should have only a small percentage of acids, moisture, fats or other impurities. It should be free from sour odors, clear and uniform in color, and should be in the form of a powder. The powder should pass through a 50 or 60 mesh sieve.

To produce glue, the casein is mixed with lime and water to increase the working life, the water resisting quality and to improve the glue. Caustic Soda, sodium fluoride and sodium silicate are used in patented formulae. They will lengthen the life of the glue, and sodium fluoride probably gives the glue antiseptic properties. Oils are added to dry mix glues to prevent dusting in handling the glue. Several formulae for mixing have been developed at the Forest Products Laboratory. One of these has been patented. U. S. Patent No. 1,291,396 granted to Samuel Butterman and assigned to the United States Government.

Glue 4-A Formula: 100 parts casein with 130-280 parts of water soaked for 15 minutes is mixed with a mixture of 15-22 parts of hydrated powdered lime and 90 parts water. To these add 70 parts of silicate of soda. After mixing, the mixer being turned at 50-60 r.p.m., add casein. Continue

until the casein passes into the form of a mush. After a period of about 15 minutes the soaking is considered complete and the mixing blade is started again. Then add lime water, and after two or three minutes add liquid silicate of soda. Mix for 20 or 30 minutes.

Casein glue is applied by hand or machine spreader, a wire brush or metal scraper used for hand work or a bristle brush. Enough glue should be spread so that a small amount is squeezed out when pressure is applied.

The working life of the glue is from four or five hours for moderate consistency to many hours for thinner consistency. The time that elapses between the spreading of the glue and the pressing depends on the moisture content of the wood, the consistency of the glue, the kind of wood, the quantity of the glue and the temperature of the wood and glue in general. The pressure should be applied while the glue is yet in a wet condition. The pressure used should be from 75 to 100 lb. per sq. in. Unless the surface is very irregular and the glue thick the pressure should be held for at least one-half hour, although longer periods are advisable.

After removal from press the stock should be allowed to condition before being finished. The time of conditioning depends on the nature of the material. Dry casein and casein glues will keep for a long time if stored under proper conditions. The place should be cool and dry as excessive moisture and high temperature causes deterioration. Casein glues have good strength and water resistant properties. After boiling for eight hours and soaking for ten days in cold water samples glued with this glue show no separation. Address Director, Forest Products Laboratory, Madison, Wis.

Metallurgy & Metallography A10-19 Manganese Alloys in Steel. The Use of Manganese Alloys in Open-Hearth Steel Practice by Samuel L. Hoyt, War Minerals Investigations Series No. 11, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Metallurgy & Metallography A11-19 Aluminum Alloys. Special and Commercial Light Aluminum Alloys by Robert J. Anderson. Minerals Investigations Series No. 14, Bureau of Mines, Address Van. H. Manning, Director, Washington, D. C.

Metallurgy & Metallography A12-19 Manganese. Uses of Manganese Other Than for Steel Making by W. C. Phalen, Minerals Investigations Series No. 16, Bureau of Mines, Address Van. H. Manning, Director, Washington, D. C.

Metallurgy & Metallography A13-19 Flotation Oils. Oils from hard wood tar have been shown to have high flotation values. Crude tar obtained in making of wood alcohol has been shown to be as good as redistilled oils. The presence of pitch from hard wood tar and oils has been shown to be desirable and not detrimental. Forest Products Laboratory, Madison, Wis. Address Director.

Metallurgy & Metallography A16-19 Graphite. Preparation of Crucible Graphite by George D. Dub, War Minerals Investigations Series No. 3, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Metallurgy & Metallography A19-19 Graphite. Refining Alabama Flake Graphite for Crucible Use by Frederick G. Moses, War Minerals Investigations Series No. 8, Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Petroleum, Asphalt & Wood Products A1-19 Gasoline from Natural Gas. Recent Developments in the Absorption process for Recovering Gasoline from Natural Gas by W. P. Dykema, Bulletin 176, Bureau of Mines, Address Van. H. Manning, Director, Washington, D. C.

Wood Products A1-19 Hints on Storing Timber to Prevent Decay. Store on well drained ground, remove debris and keep down weeds, use proper foundations, slope timber piles, assist ventilation by avoiding close piling in the open, take care of stickers, keep sheds dry and well aired, check fungus with breaks. Technical Notes, Feb. 15, 1919. The Forest Products Laboratory, Madison, Wis. Address Director. Also Bulletin 510, Department of Agriculture, "Timber Storage Conditions in Eastern and Southern States with Special Reference to Decay Problems." Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20c.

Wood Products A2-19 Moisture-Proofing Wood with Aluminum Leaf. Aluminum leaf is very effective for water proofing woods. When exposed for seventeen days in atmosphere of 95 to 100 per cent humidity natural birch absorbed fifty-five grams of moisture per sq. ft. of surface. Wood treated with five coats of linseed oil and two coats of floor wax absorbed coat of spar varnish eight grams; with filler and three coats of spar varnish absorbed fifteen grams per sq. ft. Samples coated with filler and three coats of orange shellac absorbed ten grams per sq. ft., with filler, two coats of enamel and one coat of spar varnish eight grams; with filler and three coats of rubbing varnish, seven grams. With two coats of shellac, one coat of spar varnish, one coat of aluminum leaf, two coats of shellac and one coat of spar varnish about 1½ grams. A little less than this was obtained from one coat of spar varnish, one sizing coat of spar varnish, aluminum leaf and two coats of spar varnish. The leaf is applied from the book without the aid of gilders tips as soon as the size reaches the right condition. It is important to let the size reach the right condition just before the varnish sets dust free. It takes 1½ hr. for this condition to be reached. Forest Products Laboratory, Madison, Wis. Address Director.

Wood Products A4-19 Circulation and Piling in Dry Kilns. The Forest Products Laboratory at Madison, Wis., has shown that the piling of lumber in a kiln must suit the circulation of the kiln in order to make the product uniform and cut down the time required. In a kiln having vertical lateral circulation lumber piled endwise dried quicker and gave more uniform results. Forest Products Laboratory, Madison, Wis. Address Director.

Wood Products A6-19 Scratched and Smooth Joints in Gluing. Tests of hard maple blocks with smooth and tooth planed contact surfaces were sheared after standing one week after gluing with high grade hide glue. Eleven tests gave 1988 lb. per sq. in. for scratched joints with 35 per cent of wood surface in the fracture while eleven smooth pieces gave a shearing strength of 2040 lb. per sq. in. with 47 per cent of wood surface in the failure. Forest Products Laboratory, Madison, Wis. Address Director.

Wood Products A7-19 Kiln Drying. Quarter sawed oak was dried in kiln originally at 105 deg. fahr. with 85 per cent humidity and with final temperatures of 145 deg. fahr., 155 deg. fahr. and 165 deg. fahr. The higher temperature produced a marked difference in the drying rate without causing visible defects. Douglas Fir in 2½-in. planks required twenty hours to reduce the moisture content from 50 per cent to 8 per cent. This was reduced to fourteen hours when starting at 130 deg. fahr. and ending with 150 deg. fahr. Ten tests were required with a temperature ranging from 160 deg. fahr. to 180 deg. fahr. and eight days with temperatures ranging from 220 deg. fahr. to 240 deg. fahr. Higher humidities were used with higher temperatures. Checking, warping, and cupping were very slight, but the higher temperatures seemed to darken the wood. In drying butt log cypress a high humidity in the kiln was used with a high temperature. This increased the rate of drying without producing checking. Forest Products Laboratory, Madison, Wis. Address Director.

B—Research in Progress

The purpose of this section of engineering research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Aircraft B6-19 Air Propellers. A general study of air propellers at Leland Stanford Jr. University undertaken for the National Advisory Committee for Aeronautics, of a general

character and scope as indicated by reports of the above committee and issued as a government publication. Address Prof. W. F. Durand, Leland Stanford Jr. University, Stanford University, Cal.

Bureau of Mines B1-19 The activities of the Bureau of Mines have recently been communicated to the Research Committee of the American Society of Mechanical Engineers, and during the next few months these will be listed in this department. To show the activities, however, the following statement of the work of the Bureau is given:

Number of Problems Under Investigation or Planned by Stations

Station or Office	Number of Problems Under Investigation	Planned or Outlined	Number of Men Employed
Bartlesville, Okla	4	3	7
Berkeley, Cal	6	3	6
Columbus, Ohio	10	..	9
Fairbanks, Alaska	9	3	3
Golden, Colo	8	7	9
Ithaca, N. Y	4	4	3
Minneapolis, Minn	6	1	9
Moscow, Idaho	5	3	3
Pittsburgh, Pa	..	..	..
Chemical Research	9	2	32
Coal Mining	6	..	8*
Electrical	9	3	5
Fuels	7	7	15
Iron and Steel	1	3	1
Mechanical Equipment	1	1	1
Mine Safety	6	1	4*
Non-Ferrous Metals	1	4	1
Petroleum Research	6	2	6
Physical Testing of Explosives	8	4	6
Technical Service	4	..	12
Salt Lake City, Utah	13	13	9
San Francisco, Cal	8	2	10
Sattle, Wash	11	6	6
Tucson, Ariz	4	5	4
Urbana, Ill	8	1	7
Totals	154	78	176

*These numbers do not include various field engineers.

Fuels, Gas, Tar & Coke B2-19 Aero Fuel Development. So far most favorable fuels were (1) Hecter (a synthetic cyclohexane and benzol); (2) Gasolines using large percentage of napthane hydrocarbons; (3) Mixtures of Gasoline and benzol. W. B. Dykema, Bureau of Mines Station, Bartlesville, Okla.

Fuels, Gas, Tar & Coke B3-19 Coal Analysis by A. C. Fieldner and W. A. Selvig, Bureau of Mines Station, Pittsburgh, Pa. Analysis of standard coal samples of the United States collected from July 1, 1916, to July 1, 1919, by the Bureau of Mines. Address Bureau of Mines, Van H. Manning, Director, Washington, D. C.

Fuels, Gas, Tar & Coke B4-19 Ash. Fusibility of Coal Ash by A. C. Fieldner and W. A. Selvig, Bureau of Mines Station, Pittsburgh, Pa. Investigations on the fusibility of coal ash from the well known coals of the United States. Results on coals from West Virginia, Illinois, Indiana, Kentucky, Kansas, Missouri, Oklahoma and Arkansas have been completed and published. Tests on Pennsylvania coals have been completed and results are being compiled. Maryland, Virginia, Eastern Kentucky and Ohio coals have been tested but results are not yet available, one thousand samples are yet to be tested. A final report covering all coals will be published in the form of a Bulletin. Bureau of Mines, Address Van H. Manning, Director, Washington, D. C.

Fuels, Gas, Tar & Coke B5-19 Constitution of Coal by A. C. Fieldner and R. Theissen. An extensive investigation including a large number of photo-micrographs. These show that the bright bands or anthraxylon consist of coalified wood, while the dull bands consist of small layers of bright coal or woody chips embedded in ground mass of dull coal composed of macerated remains of cellulodic degradation products, cultlicles, spore-exines, resinous particles, etc., which are all called attritus. Bureau of Mines Station, Pittsburgh, Pa. Address Van H. Manning, Director, Washington, D. C.

Hydraulics B3-19 Surge Chambers. A research problem in power hydraulics relating to the operation of a surge chamber in connection with an adjacent auxiliary reservoir, or in effect, the operation of two surge chambers, one large and one small, and separated by a conduit about 1400 ft. in length. This combination is one which gives rise to six differential equations in order to represent the hydraulic conditions. It is therefore quite beyond the range of investigation by analytical or other direct mathematical processes. The problem is being investigated by means of a model representing a special application of the law of kinematic similitude, and in accordance with methods developed by Professor Durand as given in Transactions, A. S. M. E., Vol. 34, p. 359. Address Prof. W. F. Durand, Leland Stanford University, Cal.

Metallurgy & Metallography B5-19 Alloy Steels. Simple and Complex Steels using uranium, tungsten, molybdenum, chromium, vanadium, titanium and aluminum. Light Arrnor Plate Steels containing zirconium. These steels are to be tested physically and in some cases ballistic tests are to be made. Some are to be used in forgings and some in castings. H. W. Gillett, Field Office of the Bureau of Mines at Ithaca, N. Y. Address Van H. Manning, Director, Washington, D. C.

Metallurgy & Metallography B6-19 Aluminum Chips. Melting of Aluminum Chips. This investigation is to be continued although results of investigations by H. W. Gillett and G. E. James were published in Bureau of Mines Bulletin No. 108, (Van H. Manning, Director). H. W. Gillett, Chief Alloy Chemist, Field Office, Bureau of Mines Station, Ithaca, N. Y.

Metallurgy & Metallography B7-19 Aluminum. Metallurgy of Aluminum, Robert J. Anderson, Metallurgist, Bureau of Mines Station, Pittsburgh, Pa. Object of experiment is to prevent waste in metal and fuel and to secure and disseminate information regarding metallurgy of aluminum. Problems being investigated are:

1 Causes for and prevention of defects in aluminum-alloy castings.

2 Blowholes, porosity, and unsoundness in aluminum-alloy castings.

3 Comparison of methods of melting aluminum and aluminum alloys.

4 Comparison of methods of introducing copper into the production of aluminum copper alloys.

5 Electric furnace melting of aluminum and aluminum alloys.

6 Study of quality of aluminum ingot as related to casting practice.

7 Pyrometry for aluminum-alloy foundries.

8 Development of method of analysis for aluminum oxide in ingot and alloy castings.

Worthless alloys are being discussed in a Technical Paper now in the course of publication.

This work is being done with the coöperation of various aluminum alloy foundries.

Coöperative work is being done with The Foundry. Metallographic studies have been made. These show that micrographs to seven diameters are very instructive. Address Van H. Manning, Director, Bureau of Mines, Washington, D. C.

Mining, General B1-19 Dust. Explosibility of Coal Dust by J. W. Paul, Bureau of Mines Station, Pittsburgh, Pa. Work done at experimental mine at Bruceton, Pa. Tests are being conducted on explosibility of coal dust from mines in all coal producing states to determine the explosibility and the treatment to render dust inert to explosion influences. Address Van H. Manning, Washington, D. C.

Mining, General B2-19 Coal. Mechanical Preparation of Coal by E. A. Holbrook, Bureau of Mines Station, University

of Illinois, Urbana, Ill. Work being conducted in laboratory of the university equipped with every type of coal washing and dressing machine. Probably the best equipped coal laboratory in the country. Problems so far worked upon include coal washing tests and the separation of pyrite from coal and especially coals used for cooking purposes. Bureau of Mines. Address Van H. Manning, Washington, D. C.

Wood Products B1-19 Effect of Kiln Drying on Strength. The Forest Products Laboratory is conducting a research on the strength of lumber when dried in the kiln and when air dried. Twenty-six species are to be examined. Forest Products Laboratory, Madison, Wis. Address Director.

Wood Products B2-19 Swelling and Shrinking of Wood as Influenced by Various Treatments and Coatings. The Forest Products Laboratory has 450 test panels coated with varnish, enamel or aluminum leaf. One-half of these will be hung in the laboratory under room conditions and one-half will be exposed to the weather. The effect of exposure will be measured from time to time. Forest Products Laboratory, Madison, Wis. Address Director.

C—Research Problems

The purpose of this section of engineering research is to bring together persons who desire coöperation in research work or to bring together those who have problems and no equipment with those who are equipped to carry on research. It is hoped that those desiring coöperation or aid will state problems for publication in this section.

Fuels, Gas, Tar & Coke C1-19 Alcohol. The Commercial Applications of Alcohol Fuels. Work is being done on this problem by a number of engineers and manufacturers, but other applications are needed to increase the demand for this fuel. Address Prof. Charles E. Lucke, 117th Street and Broadway, New York.

D—Research Equipment

The purpose of this section of engineering research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories so that persons desiring special investigations may know where such work may be done.

Aircraft D5-19 Wind Tunnel. The tunnel of the Bureau of Standards has been altered to permit the attainment of air speed up to 180 miles an hour. Address Bureau of Standards, S. W. Stratton, Director, Washington, D. C.

Stanford University D1-19 Laboratory of the Department of Mechanical Engineering.

1 *General Laboratory:* Miscellaneous instruments and equipment necessary for general problems including dynamometers, measuring instruments for pressure, time, revolutions, electrical quantities, etc.

2 *Laboratory of Steam Prime Movers:* Simple and compound engines of various kinds, including special Nordberg corliss experimental engine; one high pressure B. & W. experimental boiler; one vertical tubular boiler; one horizontal tubular boiler.

3 *Laboratory of Internal Combustion Prime Movers:* Internal combustion engines of industrial, automatic and aeronautic types.

4 *Laboratory of Hydraulic Machines:* Various forms of pumps and water wheels with special facilities for the investigation of problems in power hydraulics.

5 *Laboratory of Aerodynamics:* Special wind tunnel of circular section 7 ft. 6 in. in diameter equipped for wind velocity up to 60 m.p.h. Especially intended for problems relating to air propellers.

6 *Miscellaneous Equipment:* Mechanical refrigerating unit for measuring and testing various quantities in refrigerating problems. One piston air compressor. One turbine air compressor. Apparatus for use in problems of lubrication, bearing friction, etc. Address Prof. W. F. Durand, Leland Stanford Jr. University, Cal.

E—Research Personnel

The purpose of this section of engineering research is to give notes of a personal nature regarding the personnel of various laboratories, methods of procedure for commercial work or notes regarding the conduct of various laboratories.

During the absence of Dr. Van H. Manning, Prof. O. P. Hood of the Bureau of Mines has been Acting Director.

F—Bibliographies

The purpose of this section of engineering research is to inform the profession and especially the members of the A. S. M. E. of bibliographies which have been prepared. These bibliographies have been prepared at the request of members, and where the bibliography is not extensive, this is done at the expense of the Society. For bibliographies of a general nature the Society is prepared to make extensive bibliographies at the expense of the Society on the approval of the Research Committee. After these bibliographies are prepared they are loaned to the person requesting them for a period of one month. Additional copies are prepared which are available for periods of two weeks to members of the A. S. M. E. or to others recommended by members of the A. S. M. E. These bibliographies are on file in the offices of the Society and are to be loaned on request. The bibliographies are prepared by the staff of the Library of the United Engineering Society which is probably the largest Engineering Library in this country.

Boilers F2-19 Oil Burning Equipment for Boilers. A bibliography of one page. Search 2609. Address A. S. M. E., 29 West 39th St., New York.

Leather & Glue F1-19 Glues. A bibliography of 2 pages on Glues of Various Kinds. Address A. S. M. E., 29 West 39th St., N. Y. Forest Products Laboratory, Madison, Wis.

Steam Power F1-19 Engines for Steam Cars. A bibliography of 2½ pages. Search 2465. Address A. S. M. E., 29 West 39th St., New York.

Steam Power F2-19 Exhaust Steam from Non-Condensing Compound Engines. (No bibliography.) Search 2522. Address A. S. M. E., 29 West 39th St., New York.

Steam Power F3-19 Uniflow Engines. A bibliography of 4½ pages. Search 2580. Address A. S. M. E., 29 West 39th St., N. Y.

Steam Power F4-19 Testing of Steam Turbines in Europe. A bibliography of 3 pages. Search 2477. Address A. S. M. E., 29 West 39th St., N. Y.

Transmission F1-19 Static Electricity in Belt Drives. Search 2481. Address A. S. M. E., 29 West 39th St., New York.

Transmission F2-19 Ball Bearings in Railway Rolling Stock. A bibliography of 1¼ pages. Search 2591. Address A. S. M. E., 29 West 39th St., New York.

Sugar F1-19 Manufacture of Sugar Syrups; Maltose; and Use of Bone Black in Filters. A bibliography of 3½ pages. Search 2564. Address A. S. M. E., 29 West 39th St., New York.

Water Sewage & Sanitation F1-19 Water Softening for Industrial Purposes. A bibliography of 5 pages. Search 2579. Address A. S. M. E., 29 West 39th St., N. Y.

Water Sewage & Sanitation F2-19 Inquiry of Starr System of Sewage Disposal. Search 2575. Address A. S. M. E., 29 West 39th St., N. Y.

Water Sewage & Sanitation F3-19 Incinerators. A bibliography of 2¼ pages. Search 2596. Address A. S. M. E., 29 West 39th St., N. Y.

Wood Products F1-19 Drying Kilns and Kilns of Lumber. Search 2536. Address A. S. M. E., 29 West 39th St., N. Y.

Welcome-Home Dinner to Herbert Hoover

FEW receptions have expressed the enthusiasm accorded Herbert Hoover during a dinner held at the Waldorf Astoria Hotel on Sept. 16. The grand ball-room was filled to its utmost capacity by some 1200 of his colleagues, members and friends of The American Institute of Mining and Metallurgical Engineers of which Mr. Hoover is a member.

The honor of toastmaster was bestowed upon W. L. Saunders, past president of the society, and in his address of welcome he said, turning to Mr. Hoover: "Here we have the example of an engineer who typifies the modern definition of engineering which is thus written in large letters on the wall of the engineer's library in New York: 'Engineering, the art of organizing and directing men, and controlling forces and materials of nature for the benefit of the human race.'"

In referring to Mr. Hoover's strongest characteristic, capacity to think straight in advance, the toastmaster said: "While Congress was hesitating and amending the Food Act Bill, Hoover was busy organizing every state and territory, even going into counties of each state, so that when the bill was finally passed the machine had been completed and was ready to function. His abiding faith in public opinion is based upon the belief that the people will always support an effort to do that which is right."

Herbert Hoover is a graduate of Stanford University. He first served with the United States Geological Survey, then went to West Australia and China, in mining activities. Shortly after America entered the war Mr. Hoover was summoned to Washington to take charge of the food situation here. The problem was a large one as food demands from Europe were centered upon the United States. His organization in every state and county comprised 8500 men and women, giving their whole time to the Food Administration. In addition to this there were half a million persons registered and ready to be called upon for emergency work. Twelve million families were pledged to support the work. It has been estimated that this administration carried out its functions, 92 per cent by voluntary effort, 7 per cent by persuasion and 1 per cent by legal authority.

"Immediately after the armistice was signed Mr. Hoover was directed to proceed to Europe to investigate the part that America could play in the relief of the civilian population. Though he had but four days before sailing he arranged for the purchase and shipment of 250,000 tons of food. It was not until February of the following year that Congress appropriated one hundred million dollars for European relief. At that time several hundred thousand tons of food-stuffs had been actually distributed. Up to a recent date over three million tons of food-stuffs, valued at over seven hundred and seventy million dollars have been distributed.

Mr. Hoover's speech reviewed his impressions gained since the armistice. He said that as a result of the stupendous social ferment and revolution which has existed, the people of Europe have been attempting to find a solution for their social ills by practical experiments in socialism, resulting in bankrupting the productivity of industrial commodities.

"In the situation which existed in Europe, with its desperation, greed, century-old animosities, its idealistic and proper aspirations, there was only one hope; that hope, expressed by every city and state, was that the American people, being the one disinterested and uncrippled economic and political force, still existing in the world, should again intervene. It was in response to this call that the President, comprehending the real heart of the American people, intervened in Europe a second time and took those steps which resulted in a practical economic organization of Europe pending the consummation of peace and the arrival of the forthcoming harvest.

"I cannot pay enough tribute to all these thousands of Americans, many of them engineers, men taken from the common life of the United States, who were thrust into the face of staggering political economic problems, the solution of which must affect the well-being, not of hundreds, but of millions. The proof of their performance lay in the fact that Europe has come through the most terrible period of its history with no loss of life from economic causes, with a stronger democracy and a glow in its heart for the United States.

"These matters have been brought to a successful close with the arrival of the harvest and the prospect of peace. What the future has a right to demand from us in further economic support is not yet clear, but it is at least certain that if the world cannot quickly secure the settlement of peace and safeguards for the future through the League the whole of our two great interventions in Europe will have gone for nothing, and the menace of reaction will again return against us upon the wings of chaos."

In Russia the majority of their people were comparatively well fed, warmly clothed and housed, but due to their ignorance it was possible to introduce most desperate conditions. "Socialism was brought in overnight at the hands of a small minority of intellectual dilettante and criminals. And this tyranny of minority, more terrible even than the old, has now had nearly two years in which to effect the conversion of the wicked competitive system into the elysium of communism. Two-thirds of the railways and three-fourths of the rolling stock that they control are out of operation. The whole population is without any normal comforts of life and plunged into the most grievous famine of centuries. Her people are dying at the rate of hundreds of thousands monthly from starvation and disease. The capital city has diminished in population from nearly 2,000,000 to less than 600,000. The streets of every city and village have run with the blood of executions. Nor have these executions been confined to the so-called middle and upper classes, for lately the opposition of the workmen and farmers to this regime has brought them also to the firing squad in appalling numbers."

Herbert Hoover

The aims of socialism were thus defeated and in reversing their methods are now trying to summon back the forces of production, for we know that country has ample supplies of food, coal, oil, wood, flax, cottons and metals and the factories with which to work them and that their sole deficiency is human effort.

"My conclusion from all these observations is, therefore, that socialism as a philosophy of possible human application has already bankrupted itself. Bankruptcy of the socialist idea, however, does not relieve us from the necessity of finding a solution to the primary question in the better division of the products of industry and the steady development of higher productivity. The bankruptcy of the socialist idea should, if reaction is to be prevented, return the guardianship of this problem from the radical world to the liberal world of moderate men, working upon the safe foundations of experience."

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of MECHANICAL ENGINEERING by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

Theory of Tolerances

TO THE EDITOR:

The writer noted with considerable interest an abstract of an article from Le Génie Civil, May 3, 1919, in MECHANICAL ENGINEERING of July 1919, on Theory of Tolerances. This subject has developed in the machine shop and has, up to recently, received comparatively no attention from theoretically-trained men. Mathematicians have played with the theory of probability, but a gap has been left between the mathematicians' results and machine-shop requirements.

Judging from current technical literature, the above-mentioned gap is going to be bridged and great value will result thereby.

The writer disagrees with the methods of analysis on some points used in this article, believing them to be unsound and likely to be very misleading in the initial stages of this subject. The following remarks are, therefore, made for the purpose of correcting these supposed defects and in the hope of encouraging further discussion on this subject.

The probability curve is admittedly the basic starting point. However, it is very necessary that this be applied with a considerable mixture of common sense, for possibly in no branch of mathematics can false steps be so easily made as in the application of probability theory. The psychology of the operator must be kept in mind all the time.

Fig. 14, of the article referred to, shows the result of an asymmetrical system of tolerances but very rarely represents the facts. The physical interpretation is that the operator tried to make all these shafts of diameter a as nearly as possible. Then the inspector chose both a positive and a negative tolerance, but unequal. Surely, if the inspector is going to use unequal positive and negative tolerances, then the operator will be aware of this before he does the work in question. In the interests of economy the operator certainly should be aware of this, and usually always is. This being the case, it is a rational guess that he plays for the mean of the high and low permissible diameters. Briefly, he uses the available tolerance to the best possible advantage. If he does this then Fig. 14 would change so that the axis of symmetry OY will be exactly in the middle of the shaded area, as is the case in Fig. 13. To restate the case, no matter how asymmetric the tolerances might be in respect to the nominal shaft diameter, the operator will interest himself with the limits and this reduces the case to a symmetric one.

In Figs. 18 and 19, it is seen that the controlling factor in stepping from Case 1 to Case 2 is to keep the theoretical play constant. This seems somewhat artificial. From the standpoint of a designer the theoretical play, which is really average play, is not a feature of prime importance. The minimum play is an important feature, as this will measure the risk of seizing; also, the maximum play is an important feature, as this might interfere with accuracy. As to which of these two is the more important depends entirely upon the particular bearing under discussion. It would appear more rational, as a rule, to decide upon a minimum play and then let tolerances be controlled by manufacturing convenience, keeping, of course, the maximum play as small as possible. The writer believes that the complete results of the argument, centering on Figs. 18 and 19, are invalidated due to an artificial hypothesis having been taken.

Figs. 20 and 21, which are used in discussing a comparison between symmetrical and asymmetrical tolerances when the tolerances are suddenly cut in half, are particularly misleading. The following free translation of these diagrams is given in order to bring out the error:

Fig. 20 says that a man is grinding shafts and aiming at a diameter D. Then his results would show variation of diameters represented by the given curve. This is perfectly true provided he made an infinite quantity and it may be taken as true in principle for a small quantity. He makes exactly 50 per cent of these shafts oversize and 50 per cent undersize, as would be expected. The total shaded area, if suitable units be taken, represents the number of shafts ground within tolerance t. Any area under the curve and outside the shaded area represents scrap. The doubly-shaded area, to the same units, represents shafts within tolerance $\frac{1}{2}t$

$$\frac{\text{Shafts within tolerance } \frac{1}{2}t}{\text{Shafts within tolerance } t} = \frac{\text{Doubly-shaded area}}{\text{Total shaded area}}$$

Fig. 21 says that the operator endeavors to make shafts of diameter exactly D but that these are inspected on the basis of a minus tolerance t. Now if this were so, what would be the results? Obviously there would be exactly 50 per cent scrap. Fig. 21 appears to be based on the assumption that the operator does the work in the belief that both plus and minus tolerances are allowable, and then the inspector decides to use only a negative one. The diagram, Fig. 21, is distinctly incorrect. It could be justified only on the assumption of 50 per cent scrap existing, which is clearly an untenable position. Excluding this, then we must assume the operator knew that a negative tolerance only would be permitted. Under these circumstances let us temporarily assume he would endeavor to strike the mean permissible diameter. Then the axis of symmetry OB would be exactly in the middle of the figure where line cC now is. In this case, of course, Figs. 20 and 21 become identical, the results identical, and the whole case that is being pleaded, namely the advantage of the symmetric over the asymmetric system, fades away as the two merge into each other, so far as results are concerned.

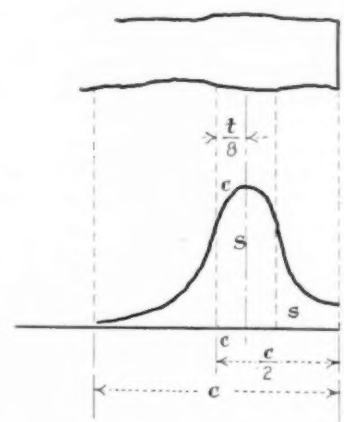

FIG. 1 AVERAGE PROBABILITY CURVE SUGGESTED BY THE WRITER

Actually there are rational arguments for moving the axis of symmetry of the probability curve a little to the right in Fig. 21. An operator who had a perfectly mathematical instinct would attempt to make the diameter exactly the mean of the maximum and minimum permissible diameters. However, there are various psychological traits, which make the operator differ from a perfectly mathematical one. For instance, an operator, who was a high-grade mechanic, might take sufficient pride in his work virtually to reduce the permissible tolerance and try to play more

nearly to the maximum diameter. Probably most of us know from observation that this is usually true, although it is not the soundest business. Furthermore, there is a natural tendency on the part of an operator to play on the big side due to the ever present instinct that he can take off but that he cannot put on. The diagrammatic result of the above two points would be to displace the axis of symmetry of the probability curve somewhat to the right. Just how much depends upon the individual operator. It is probable that an average operator would give a curve similar to the writer's, shown in Fig. 1.

Yours truly,

J. Airey.

East Moline, Ill.

Industrial Relations

To The Editor:

The following quotation is from a paper read before the National Conference of Social Work at Atlantic City on June 2 by Hon. Basil M. Manly who in acting with Hon. Wm. H. Taft as joint chairmen of the National War Labor Board has probably had a better opportunity than anyone else to obtain a correct interpretation of existing conditions with regard to labor conditions and their possible developments.

> We are about to enter a period of the most acute industrial unrest and the most bitter industrial controversy that the American nation has ever known. Unless effective and radical steps are taken to bring about a better understanding between labor and capital and to establish an equitable basis for orderly industrial progress we are certain to see within the next year strikes and mass movements of labor beside which all previous American strikes will pale into insignificance. Those who regard the American industrial situation with complacency ignore both the psychology of the workers and the compelling facts. The workers of the Allied world have been told that they were engaged in a war for democracy; that out of the ruins of war would arise a new and more beautiful world. They are asking now where is that democracy for which they fought. When are we to enter into this new world with its greater regard for the rights of the common man? They see no change for the better but they find themselves in conditions in many respects worse than those against which they protested before they entered the war. The masses of the people are being rapidly disillusioned ano when the people lose their illusions there is danger ahead.

Mr. Manly says further that workers now realize more than ever the autocratic control of industry in which the majority of the people of the country are participants and that there can be no real democracy where the people are under autocratic rule during the greater number of their waking hours. So they are fighting for the democracy here that they fought for abroad and they want to have something to say in the control of the management of their affairs. They feel that they are partners in business and they are demanding that they be recognized in that capacity.

Here is a terse and concise statement of facts and a plain warning of what may happen, and what are the members of this Society, many of whom are employers of labor, doing to meet the serious situation thus described as confronting them?

The Committee on Industrial Relations has advised against "establishing a standing committee on relations between employer and employe" and "entering the controversial field of industrial economics as involved in the relationship between employer and employe."

The only constructive suggestion, if it can be so construed, is from a member of the Committee on Aims and Organization who advises the Society that "there should be an awakening that will match and help to head off the stampede of those who are doing things with their hands." And how does he recommend that this shall be done? He says "*if we select the right slogan* the activities of the country will no longer be handicapped by unwise guidance of labor." Now the dictionary says a slogan is "a Scottish war cry" and if we are only to resort to a war cry to bring about the wonderful results prophesied by this committee man, we should have an American one which logically would be an Indian war whoop and "whoop it up" as in the good old pre-war days, and by hiring and firing and lockouts and shut-downs, head off the threatened stampede. Then of course we may expect the workers to come back with their tomahawks raised and we will continue to have each house divided against itself, resulting in the same old inefficiency.

But the way to meet the present discontent is not to assume the right to fire and lockout for that implies the converse right to leave and strike at will and we know now and should have known long ago the cost of labor turnover if we had given the thought we should have to the psychology of the workers and to industrial economics. And we are too apt to forget our responsibility to the community to whom we commit those whom we fire and lockout and which has to bear the expense of our inefficient management.

What is necessary is for employer and employe to get together and drop these strong-arm methods and work for their own and the community's welfare. Democratic methods have been working satisfactorily in so many industrial plants and for so long a time that there can be no excuse for the continuance of autocratic methods by employers. I do not know of any plant in which democratic methods have been properly introduced and maintained where either employer and employe would think of reverting to what existed previously.

The Government through the War Labor Board has recommended employes' representation in management in more than one hundred plants doing work for the Government. The War Department is now introducing these democratic methods in the Arsenals. The employes' representatives in the Rock Island Arsenal have stated in a report to Secretary of War Baker that a condition of antagonism and distrust had developed owing to the autocratic methods long existing but that since the employes have their shop committees "they no longer feel like mere employes, simply bent on holding down a job quite apart from their conception of life, for no other purpose than the earning of wages, the only crude means available to them for securing the necessaries and perhaps a little of the better things of life. They are beginning to see that they are on their way towards becoming partners in a large enterprise." Whereas, before the introduction of democratic methods they not only refused to have the Taylor system of Scientific Management introduced but deliberately restricted production, they now ask for technical experts to help them and say that under the new spirit dominating the men "a spontaneous efficiency is in the making which we sincerely feel will before long produce records of production that will make the most ardent Taylor system advocate envious. And this will all be because the employes want to produce not because they are obliged to do so." There is all the difference in the world between volition and compulsion, the will to do and enforced obedience. The new spirit is cutting cost in half now. What will it do under the willing guidance of technical experts?

Secretary Baker verifies these statements and says that the committees which the employes have formed are coöperative with the management who thereby have lost no control which they cannot yield as they are held responsible by the Government for results.

It has been asked how great a part shall the workers be granted control in industry. They should be granted all the control that they are capable and competent to exercise. They will not want more for they are human beings and are looking out for their own interests which are involved in the success of the enterprise. Already in many of the plants in which democratic methods are installed, including the Government arsenals, the foremen are elected and so become leaders instead of drivers. In some other plants the workers are represented in the Board of Directors. The employes should be considered as partners and so treated. They should be taken into confidence and authority and responsibility apportioned where it properly belongs, a square deal and fair play should be the principles adopted and no slogan can take their place.

When these democratic principles are properly operating the employe works with increased efficiency and the cost of product is thereby reduced. The greater profits which accrue are then divided equitably between the employer in increased dividends, the employe in higher wages and the public in lower costs. Thus the three partners in business coöperate. How many employer

members of the Society are doing their part to lower the cost of living in this manner?

It seems to me that it is high time that the members of this Society who are both engineers and employers and therefore well qualified to analyze the problems inherent in the situation, if we expect to be recognized as taking an active, even if not a leading part, in the large and important questions of the day affecting the public welfare, should do something more than have qualified speakers talk at meetings as the committee recommends. We have had enough talk on the subject and gotten nowhere. Now we should have a standing Committee authorized to do something definite.

H. F. J. Porter.

New York, N. Y.

WORK OF THE BOILER CODE COMMITTEE

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York City.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering, in order that any one interested may readily secure the latest information concerning the interpretation.

Below are given the interpretations of the Committee in Cases Nos. 240-246, inclusive, as formulated at the meeting of June 27, 1919, and approved by the Council. In this report, as previously, the names of inquirers have been omitted.

Case No. 240

Inquiry: Is it necessary under the rules of the Boiler Code to use an internal feedwater delivery pipe in the boiler of a traction engine, and also if such internal delivery pipe be omitted, is it necessary to use a boiler bushing?

Reply: Neither the boiler bushing nor internal feed pipe is required for boilers of the locomotive type, as will be observed by reference to Par. 315 of the Boiler Code.

Case No. 241

Inquiry: Are we correct in our understanding that under the requirements of Part 1, Section 2, of the Boiler Code:

a There are no restrictions as to the manner of making rivet holes?

b There are no particular requirements as to the method of suspending the boiler?

c A manufacturers' Data Report is not required?

d An inspector's affidavit is not required by Par. 373, if the manufacturer should furnish a data report?

e We have the right to stamp a heating boiler which conforms to the requirements of the Boiler Code with an A.S.M.E. Stamp without having a state inspector present?

Reply: *a* and *b* Your understanding is correct.

c Your understanding is correct as far as the requirements of the A.S.M.E. Boiler Code are concerned, but the actual requirements in any particular locality in regard to this will, of course, depend upon the local laws governing boiler construction there.

d The requirement for the inspector's affidavit on a Data Report, if furnished, will depend on the laws of the localities where Manufacturers' Data Reports are required.

e Under Par. 377 of the Boiler Code, it is permissible to mark all heating boilers built according to the Code Rules with the designation "A.S.M.E. Standard." In regard to the feature of inspection, this will also depend entirely on the laws of the locality in which the boiler is to be installed.

Case No. 242

Inquiry: Is it permissible under the requirements of the Boiler Code to use "marine steel" in lieu of firebox steel for a boiler to be stamped A.S.M.E. Code standard, if the marine steel has chemical and physical properties very similar to those required for Boiler Code material?

Reply: If the "marine steel" will conform in all respects to the specifications for boiler plate steel given in the Boiler Code, and is re-stamped by the manufacturer in the way specified in the Code, it may be employed in the construction of Code boilers.

Case No. 243

(In the hands of the Committee)

Case No. 244

(In the hands of the Committee)

Case No. 245

Inquiry: Is it permissible under the requirements of the Boiler Code to close up handhole openings in a boiler by the use of oval plates slightly larger than the handhole openings, placed inside and welded tight against the opening by the electric welding process?

Reply: If the plate which is placed on the inside of the opening is as strong as would be employed in the cap of a handhole fitting, or the like, which would not be welded to the boiler, there is nothing in the Code to prohibit the construction described except where the temperature of the gases striking the surface would limit the allowable thickness of the material. This is in accordance with Par. 186, which specifies that autogenous welding may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

Case No. 246

Inquiry: Will low-pressure heating boilers of the double, return-tubular type, with all joints welded instead of riveted, but which are built for heating service only, comply with the Rules of the Boiler Code? It is pointed out that the electric process of welding is used in this construction throughout and advised that all the boilers built in this manner have been operated for low pressure heating service (not exceeding 15 lb.), and that no trouble has ever resulted with them.

Reply: When the heating boiler section of the Code was formulated, welded joints were not considered for heating boilers. In general, the Code Committee does not approve of autogenous welding for any joint subject to tension (see Par. 186). This matter of welding joints for heating boilers is being referred to the Sub-committee on Heating Boilers and to the Sub-committee on Welding of the Boiler Code Committee.

According to the *Scale Journal* of July, 1919, the Pennsylvania Railroad has just completed one of the largest engines, and possibly the heaviest, ever built. The engine alone, without the tender, weighs 610,000 lb. As the engine is longer than the scale at Harrisburg, Pa., upon which it was weighed, its total weight was placed on the scale by means of jacking up the pilot wheels clear of the track and chaining them to the frame, thereby hanging them from the engine frame; thus, the total load of the engine was on the scale.

ENGINEERING SURVEY

A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

AERONAUTICS

Engine Designed to Operate at High Altitudes

The Napier Lion Aircraft Engine. Description of an engine very unusual in several respects. In the first place, it is unique in being the only example of its type which has been accepted by the Air Ministry as a "program" engine in that it is of the triple-four type, being of three rows of four cylinders each.

Next, it is lighter per horsepower than any water-cooled aero engine yet produced [a statement, which, however, has to be qualified by the fact that it is by no means certain what rating an engine of this type should be given, as will be evident from what follows].

The relation of the three rows of cylinders may be understood from Fig. 1 which gives a section through the timing gears. The engine was originally designed for work at high altitudes. The initial specifications of the Air Ministry required an engine at full throttle at a height of 10,000 ft. only, and to give at that altitude not less than 300 hp. These requirements have been amended to read that the engine would not be expected to run at full throttle at ground level.

The three rows of cylinders are at an angle of 60 deg. between the rows, which gives a short though fairly broad engine. Four overhead valves per cylinder are fitted and are operated by two overhead camshafts per row of cylinder. The cylinder blocks are built up of a single casting, forming the head for the four cylinders into which are secured separate steel barrels with water jackets made up of thin sheet steel. The crankshaft is a simple four-throw type mounted on roller bearings with a reduction gear between it and the propeller hub of simple spur type.

The inlet valves are of phosphor bronze and the outlet and exhaust valves of steel. Separate valve seats are used and the makers state that they have not expressed any trouble with them, while, on the other hand, the flanged valve seats form a convenient method of fastening the cylinder barrels and heads together. The writer criticizes this arrangement claiming that it makes the construction inaccessible and the removal of a valve difficult.

An interesting problem came up in connection with the connecting rod assembly. In this type of engine three connecting rods work on to a common crankpin and the method adopted (Fig. 2) has been to use a central master rod on each side of which is mounted an articulated rod carried on wrist pins fixed in lugs integral with the big end of the master rod.

The most remarkable part about the engine is the arrangement made for permitting it to run at high power at extremely high altitudes.

[The engine is really what might be called an "undercharged" engine (as opposed to the conventional idea of a supercharged engine) in that it has been designed to operate at an air density lower than the atmospheric.

The compression ratio is 5.55 to 1, which is an exceedingly high figure, but the engine is not designed to operate at full throttle at sea level but only at high altitudes. Therefore, notwithstanding the very high compression ratio the actual compression pressures at which the engine operates do not differ materially from those at which engines of conventional design operate at sea level.

This required, of course, great care and skill in design but the result is an engine with which a ceiling of more than 30,000 ft. has been reached.]

Fig. 4 is of interest as it gives the average power curve of the engine based on official tests taken over a number of engines at ground level and corrected for the barometric reading. The weight of the engine complete without water, fuel or oil is approximately 840 lb. and the gross weight of the engine in running order but without fuel and oil is 1132 lb. With fuel and oil for six hours it weighs 2671 lb. The engine is of 5.5-in. bore and $5\frac{1}{8}$-in. stroke, giving a total volume of the engine of 1461 cu. in., and a normal piston speed of 1708 ft. per min. (*The Automobile Engineer*, vol. 9, no. 129, August 1919, pp. 250-258, 29 figs., *d*)

BLAST FURNACES (See Gas Engineering)

ENGINEERING MATERIALS (See Heat Treatment)

FUELS AND FIRING

By-Product Recovery from Coal in Power Plants Practically Paying for Fuel

Low-Temperature Distillation of Coal, C. M. Garland, Mem.Am.Soc.M.E. An article which makes claims deserving the most careful consideration. Among other things, that for power plants with constant load burning over 50 tons of coal per day a combination of the low-temperature process with the by-product gas producer to recover ammonium sulphate improves economy to such an extent that the by-products pay for the coal, the overhead and operating expense, while the gas containing about 70 per cent of the heat in the coal and burning at higher efficiency is available for fuel under the boilers or for direct use in gas engines.

Low-temperature distillation is carried out in closed retorts at temperatures ranging from 700 to 1200 deg. fahr. The coke produced is much softer than in high-temperature distillation, but it has sufficient mechanical strength for all practical purposes, permits the maintenance of a fuel bed under low draft and burns without smoke notwithstanding the fact that it has from 3 to 18 per cent of volatile remaining in it. It is, however, not suitable for metallurgical operations.

As regards by-products, from 20 to 30 gal. of tar are produced per ton of coal. This tar contains a high percentage of pitch and free carbon and also a high percentage of tar acids suitable

for wood preservation, as well as low boiling distillates suitable for motor fuel. Investigations indicate that this tar at the present time has a value close to 10 cents per gal. in the crude state.

The temperatures in the low-temperature process are too low to yield much ammonium sulphate. The volume of gas produced is also low and varies from 1000 to 4000 cu. ft. per ton of coal. The gas has a heat value of from 750 to 1000 B.t.u. per cu. ft.

The author briefly describes the processes of Traer, Bostaph, Smith ("Carbocoal"), and G. & L. The essential differences between the processes are, as follows: In the process of Traer and

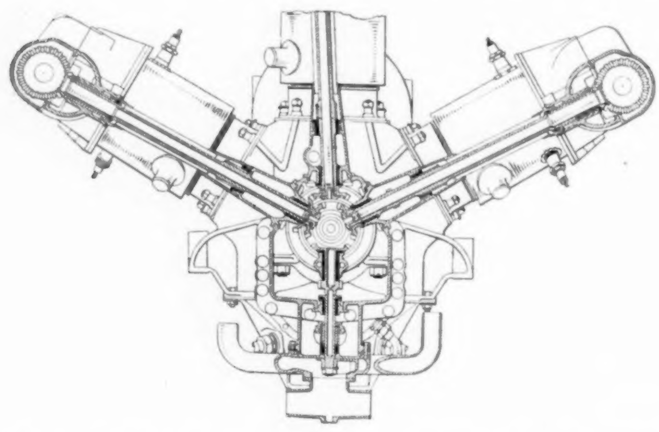

Fig. 1 Napier Lion Aircraft Engine Section Through Timing Gear

Bostaph the coal is coked in cast iron forms, in the Traed process in a vertical form divided by partitions to produce rectangular slabs of coke about 4 x 12 in. in cross-section by 6 ft. in length. In the Bostaph system the coal is coked in the form of slabs, but these slabs form segments of a cylindrical drum which is provided with a hollow core for drawing off the products of distillation. Furthermore, in the Bostaph process the heat is supplied externally and the products of distillation pass through perforations in the inner wall of the retort to the central core, the idea being that the products of distillation should not come into contact with a higher temperature than from which they are distilled, as such contact may result in the chemical breaking up of the products.

In the carbocoal process the coking is carried out in two stages, the first stage being straight distillation of the coal, which gives a finely divided coke with a high percentage of volatile. This coke is mixed with some pitch and briquetted, the briquets being then subjected to a temperature in the neighborhood of 800 deg. fahr. which cokes the pitch and drives off most of the volatile.

The tar from the low-temperature process yields a large quantity of oil suitable for motor fuel, and it is possible to increase this quantity still further by cracking the tar.

The author believes that ultimately it will be possible to combine this low-temperature process with a by-product recovery gas producer, such as the Mond producer, and recover ammonia in the form of ammonium sulphate.

An important limitation to the application of this system lies in the fact that installations of this character are adapted only to plants using 50 tons or more of coal per 24 hr. and operating continuously 24 hr. per day and preferably every day in the year. On the other hand, it would mean that a plant using as much as 50 tons per day with an ammonium sulphate recovery of 85 lb. per ton of coal would generate power practically at no cost, while a larger plant may even have a small surplus after the disposal of the by-products. (*Power*, vol. 50, no. 7, Aug. 12, 1919, pp. 248-251, 4 figs., *dg*)

FURNACES

Use of a Modified Rosenhain Furnace for Thermal Analysis, H. Scott and J. R. Freeman, Jr. Rosenhain in 1915 published a description of a furnace for the thermal analysis of metals operating under a new principle. Instead of carrying the temperature of the furnace containing the specimen under investigation, he heated the furnace so as to produce a uniform temperature gradient along its length and moved the specimen through the furnace. The present paper describes in detail some improvements in the design of his furnace and considers certain features of its operation. A simple method of mounting is described which gives highly satisfactory results using specimens of less than 2 grams weight. (*Abstract of Scientific Paper* No. 348, *U. S. Bureau of Standards*, *d*)

GAS ENGINEERING

Gas Washers, Geo. B. Cramp. The article discusses the general principles of gas-washer construction and operation and suggests a certain design which is claimed to increase the efficiency of gas washers. In order to secure a thorough and efficient wet washing of the blast furnace gas, it is necessary, the author states, to subdivide the gas volume into as small bodies as possible and bring them into intimate and positive contact with as small an amount of water as will clean the gas to the desired limit of dust content without too great a reduction in the temperature of the gas.

Washers having sprays of water directed on baffles between which the gas must pass give a positive contact of gas with water, but their efficiency depends upon a number of conditions, such as uniformity of water, distribution and uniformity of baffle arrangement and area of baffle space. Of these conditions, the first, uniformity of spray, may be considered as satisfied in the modern spray nozzle and it only remains to arrange judiciously the nozzles themselves to secure a uniform distribution of water over any area greater than one nozzle spray can cover. The next point is, therefore, the selection of the baffle shape to be used in the washer. The writer considers several shapes of baffles, such as, straight, angular and wavy (corrugated) and gives preference to this latter type. Corrugated sheet is a commercial shape in general use and can be readily bent without deformation of its corrugations to fit within a cylindrical shell of a gas washer. Furthermore, the corrugations permit the wash water to flow evenly down the entire surfaces of the plates while preventing the gas from travelling in a straight line, and cause it to deviate, eddy, and wind its way between the plates, so as to bring it time after time into contact

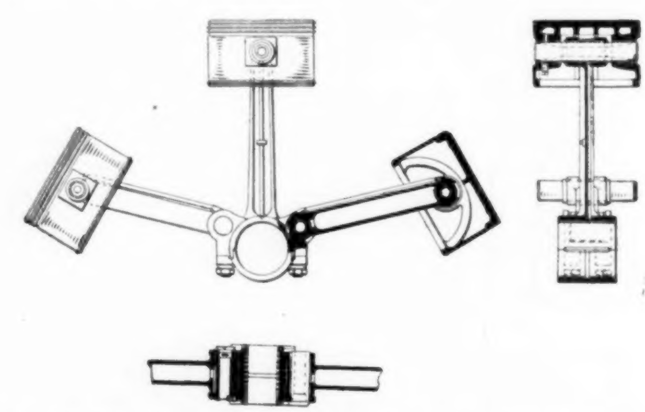

Fig. 2 Napier Lion Aircraft Engine Assembly of Connecting Rods and Pistons

with the perfectly flush surfaces at the baffles and in so doing remove a far greater amount of dust from the gas.

The writer describes in general terms the construction of a washer using corrugated sheets. (*The Blast Furnace and Steel Plant*, vol. 7, no. 9, September 1919, pp. 430-432, 4 figs., *d*)

HEAT TREATMENT

The Heat Treatment of Duralumin, P. D. Merica, R. G. Waltenberg, and H. Scott. The heat treatment of alloys of the type, duralumin, was investigated and the effect observed of variations in the heat treating conditions, such as quenching

temperature, temperature of quenching bath, and of aging or tempering, and time of aging upon the mechanical properties.

Conclusions were drawn relative to the best conditions for commercial heat-treating practice for this alloy. The temperature of quenching should not be above that of the $CuAl_2$ aluminum eutectic, which is usually about 520 deg. cent., but should be as near to this as possible without danger of eutectic melting. The pieces should be held at this temperature from 10 to 20 min. and quenched preferably in boiling water. The hardening may for most purposes best be produced by aging for about 5 days at 100 deg. cent.

A theory of the mechanism of hardening of duralumin during aging after quenching from higher temperatures was developed which is based upon the decreasing solubility of the compound $CuAl_2$ in solid solution in aluminum with decreasing temperatures from 520 deg. to ordinary temperatures. It is believed that the precipitation of excess $CuAl_2$, which is suppressed by quenching, proceeds during aging, the precipitation taking place in very highly dispersed form. The hardening is due to the formation of this highly dispersed precipitate.

According to this theory the hardening of duralumin during aging or tempering after quenching presents a very close analogy with that of steel, and the evidence in support of the theory is of the same nature and of approximately the same competence as that in support of the prevailing theory of the hardening of steel. (*Abstract of Scientific Paper* No. 347, *U. S. Bureau of Standards*, *t*)

HOISTING MACHINERY

British Standard Crane Developed During War by the Government

A BRITISH CRANE. Description of the standard crane developed during the war by the Technical Branch of the Directorate of Inland Waterways and Docks. By the end of April 1918 some 200 steam cranes of this type, known as the I. W. D. standard, were completed.

The crane was designed to perform the ordinary work of a traveling crane on the standard British railway gage and to be capabile of easy conversion into a floating, fixed or gantry crane for dock or general purposes. The conversion is effected without alterations to the machinery or ropes by using special jibs and extra balance weights.

The crane is designed to lift loads up to $2\frac{1}{2}$ tons on a single

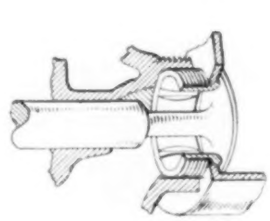

FIG. 3 NAPIER LION AIRCRAFT ENGINE VALVE SEATING

rope direct off the barrel, greater loads up to 10 tons being dealt with by a block. The lifting barrel accommodates 200 ft. of working rope so that the range of lift is about 200 ft. for the single rope and $2\frac{1}{2}$-ton hook, and 100 ft. and 50 ft. for the 5-ton and 10-ton blocks, respectively.

Figs. 5 and 6 show the general arrangement of the crane and the gear. No rail clips or blocking girders have to be fitted, as the reserve stability is 50 per cent on a level track and the crane is stable backwards with jib removed and coal bunkers and tanks full.

Steam was adopted as the motive power in order to render the crane self-contained and independent of local power. The operating levers are in front of the crane on the left-hand side so that the crane driver has a clear view of his work under all conditions.

The boiler used on these cranes is No. 14 Spencer Hopwood squat pattern water-tube type designed for a working pressure of 100 lb. per sq. in. This type of boiler steams very fast, and as there are only 18 cwt. of water in the boiler, the water level has to be watched very carefully. To avoid fluctuations in the water level the cranes are provided with an independent duplex feed pump, placed on top of the water tank on the right-hand side of the crane. This enables the driver to regulate the speed of the pump to suit the work being performed (the steam valve of the feed pump is fixed to the left-hand side of the boiler). In addition to this an injector is provided as a reserve, the injector

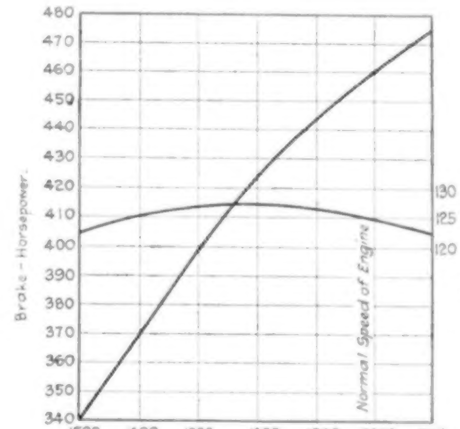

FIG. 4 NAPIER LION AIRCRAFT ENGINE AVERAGE POWER CURVE

steam valve being placed on the right-hand side of the boiler.

A standard design of fire bars was adopted, consisting of four segmental bars around the firebox with single center bars resting on the segmental bars. The use of this design enables the center bars which burn out first to be removed cheaply and easily. (*The Railway Gazette*, vol. 31, no. 7, August 15, 1919, pp. 206-210, 14 figs., *d*)

HYDRAULIC ENGINEERING

New Method for Graphically Representing Water Turbine Performance

COMPREHENSIVE PLOTTING OF WATER TURBINE CHARACTERISTICS, Karl R. Kennison. The paper presents a chart for the comprehensive plotting of water turbine characteristics intended to enable a manufacturer of waterwheels to show the performance of his turbine under any and all conditions, and also to compare the merits of different turbines and their compliance with specified requirements.

The usual system of representing test performances of a turbine by a series of curves, one for each gate opening used in the test, does not give a sufficiently clear indication of the results that would be obtained at any other gate opening not included in the test, though an engineer who specialized on the subject may be enabled to interpret these curves and fit them to any desired conditions of operation. It is claimed that the method of plotting described here is free from this objection.

Water turbine operation is determined by the following seven variable quantities:

D = rate of diameter in inches
H = head in feet
N = speed in revolutions per minute
P = power output in horsepower
Q = discharge in cubic feet per second
Gate opening
Efficiency

These quantities are interconnected by twelve simultaneous equations which the writer gives. Of these seven variables only six are independent, since power output and discharge are interrelated through efficiency and either of them may be eliminated for the sake of simplicity. Contrary to present practice, the

author eliminates power output and retains discharge capacity.

In deriving his characteristics the writer takes advantage of a fortunate mathematical coincidence, namely, that what he proposes to call specific "r.p.m." or the relation between speed, head and discharge is numerically equal to the "specific speed" currently expressed as the relation between speed, head and power output at the efficiency attained by wheels of good design, namely, 88 per cent.

The characteristics are as follows:

$$\text{Specific Head} = \frac{H \times 10^{4}}{N^2 D^2}$$

$$\text{Specific discharge} = \frac{Q \times 10^{6}}{N D^3}$$

$$\text{Specific diameter} = \frac{D H^{1/4}}{Q^{1/2}}$$

$$\text{Specific r.p.m.} = \frac{N Q^{1/2}}{H^{3/4} \times 10^{1/2}}$$

INTERNAL COMBUSTION ENGINEERING (See Aeronautics, Gas Engineering)

MACHINE DESIGN (See Power Plants)

MACHINE TOOLS

Huge Tool Doing Thirty Days' Work in Two Days

Crankshaft Lathe, Ethan Viall, Mem.Am.Soc.M.E. The full title of the article here abstracted is "A Record-Smashing Crankshaft Lathe," a title which is justified both by the design and results secured by the new machine.

The machine was the outcome of the shortage of crankshafts for multiple-cylinder oil engines of large horsepower which existed in the summer of 1917 and was designed by T. K. Webster, of Chicago, previously engaged in manufacturing a single-purpose gun-boring and shell-making machines.

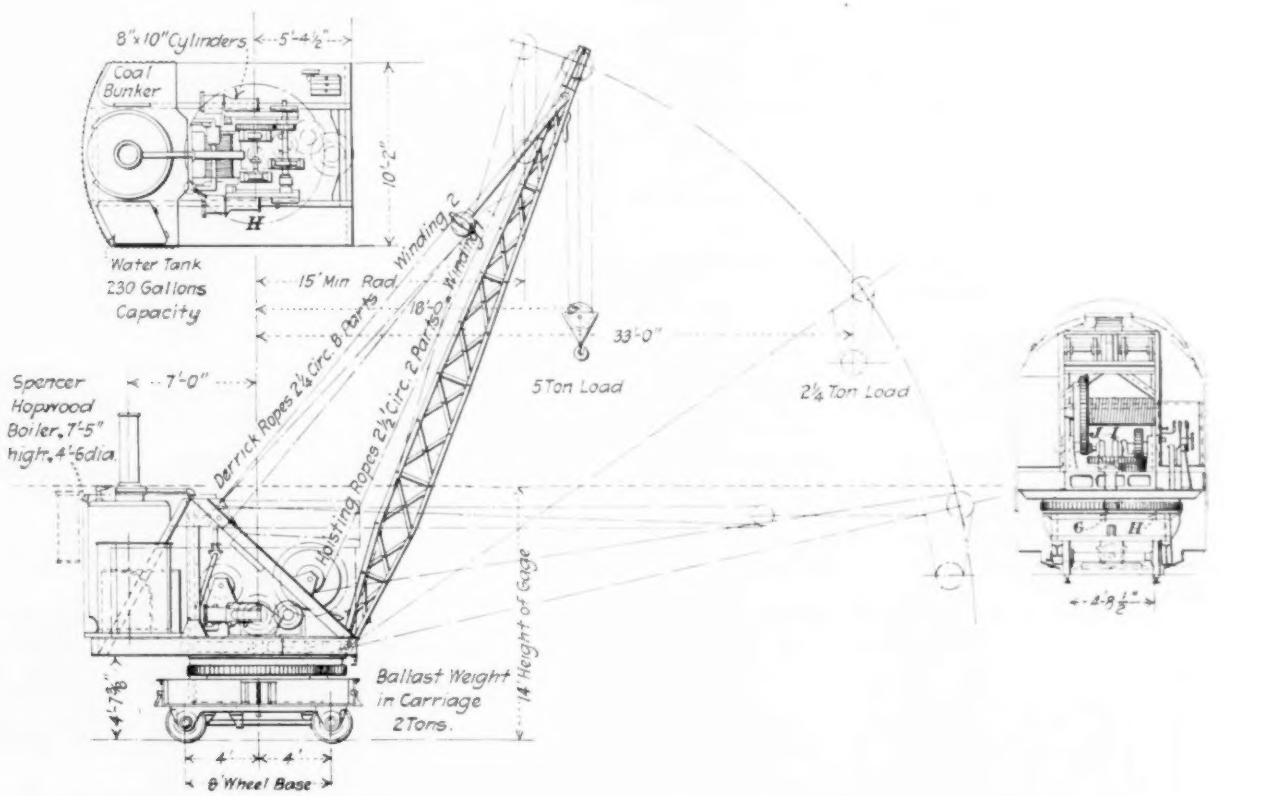

Fig. 5 General Arrangement of British Wartime Standard Steam Crane

The chart is simply a means of plotting efficiency and gate opening in terms of these four fundamental type characteristics.

The vertical and horizontal scales represent the two most important variables, namely, head and discharge, respectively, so that when the characteristic curves are plotted for any type of turbine the available range of head and discharge stand out very clearly.

A logarithmic scale of coördinates is used which permits comparing the range of operation of any two types regardless of their location on the chart. The writer gives several charts for typical water turbines of American manufacturers (inward- and downward-flow type) and describes in detail the method of using the charts. Several charts are given in the original article. (*Proceedings of the American Society of Civil Engineers*, vol. 45, no. 6, August 1919, pp. 475-481 and 3 large charts, *dp*)

HYDRAULIC MACHINERY (See Pumps)

The machine is of very large dimensions and is capable of machining crankshafts of from 7 to 10 in. in diameter and any throw. It machines the sides of the webs and turns the ends of the crankpins on all of the throws at once. Fig. 7 shows that the machine has a main and an auxiliary bed. The main bed is 33 ft. 10 in. long, 50 in. wide and carries two opposing spindles 14 in. in diameter and tool carriages after the manner of a lathe. Each of the opposing spindles is driven through back gears by means of a 20-hp. Triumph variable-speed motor with the range of 400 to 1200 r.p.m., the motors being synchronized by means of a special electrical device so that the drive on each spindle is exactly the same at all times, and no twist is imparted to the crankshaft being machined. Before the crankshaft is placed in the machine it is slabbed out, blanked by drilling and sawing, twisted according to the arrangement of the throws, centered and has the concentric bearings turned in a big lathe. Heavy-flanged driving plates are then shrunk on to each end of the crankshaft and the crankshaft is put into the machine, where it is centered

to run true and the driving plate bolted to the faceplates of the machine at each end.

The turned parts of the crankshaft run in steadyrests *A* (Fig. 8 which shows the machine with the 4-throw crankshaft in place), the bearing of which are babbitted to fit the turned parts. After this is done the crankshaft is ready for the placing of the crank-action tool carriers shown at *D*. These tool carriers have the same stroke and action as the connecting rods of the engine and are made to machine the inside faces of the crank webs and about a quarter of each end and the fillets on the crankpins.

The placing of the tool carriers is an operation requiring expert skill of high order. With the tool carriers all placed and the tools set, the machine is ready for starting. As the crankshaft revolves the two tools *H* and *I* (first tool carrier) in the sliding block are automatically fed forward and machine the inside of the webs and turn down each end of the crankpin. All the other tool carriers act in the same way. At the same time the tools in the carriages at *J* feed straight in and machine the outside faces of the webs.

While in action on the 4-throw crankshaft the machine closely resembles a huge 4-cylinder engine. One of the great advantages claimed for this method of machining is that all the webs and crankpins are machined at once. It would take 30 days to turn a 4-throw crankshaft of the size indicated in the ordinary way and it takes only two days to do the same work on this machine. Furthermore, the tools can be held close up to the cutting point, eliminating the spring, since all the tools are set out the same distance from the tool blocks for a length of throw which improves the final work.

The size of this machine may be well imagined from the fact that it weighs approximately 95 tons. (*American Machinist*, vol. 51, no. 9, August 28, 1919, pp. 395-399, 8 figs., *dA*)

Thread-Cutting Mechanism of a Norwegian Lathe. The following description is given by *Machinery* of an engine now manufactured by Broederne Sundt, Christiania, Norway. The lathe is equipped with two lead-screws for cutting both inch and metric screw threads, and the gearing is so arranged that threads of very coarse pitch, or helical grooves with leads up to 12 in., may be cut, in addition to the usual range of pitches for threads. The headstock, which is the geared type, is so designed that its gear ratios may be utilized in connection with screw cutting, the different gear combinations being used to drive the lead-screw. With this arrangement the total number of pitches obtained in the ordinary way will be multiplied by the number of gear ratios in the headstock. For example, if the lathe is set to cut ½-in. pitch, and the ratio of the gearing between the driving pulley and spindle at this particular time is 24 to 1, then by turning a handle the pitch may be changed from ½ in. to 12 in.; or if a metric thread of, say, 8-mm. pitch were being cut, the pitch would be changed to 192 mm. ($24 \times 8 = 192$).

The headstock of the lathe has eight different gear ratios, and it is said that the stress on the gearing is not much heavier when cutting the large pitches than when cutting the finer ones. There is one lead-screw for the inch pitches and one for the millimeter pitches. The metric lead-screw also serves as a feed-rod; in fact, it is practically a threaded feed-rod. When used as a feed-rod the threads are not engaged by the nut on the carriage, as there is a keyway which transmits the feed motion worm and spur gearing in the usual manner. The apron has separate nuts for engaging each screw, but they are both operated by the same handle, and only one can be engaged at a time. By means of this additional screw on the feed-rod, metric threads can be cut without using translating gears and by employing the same gearing as for the inch pitches. Both lead-screws run at the same speed, and either one may be disconnected when the other is in use. The inch lead-screw is ¼-in. pitch, and the feed-rod 4-mm pitch; hence, when the lathe is geared for cutting $\frac{1}{16}$-in. pitch, it is also geared for cutting a pitch of 1 mm. with the metric lead-screw.

The change-gear box in connection with one set of spur gears

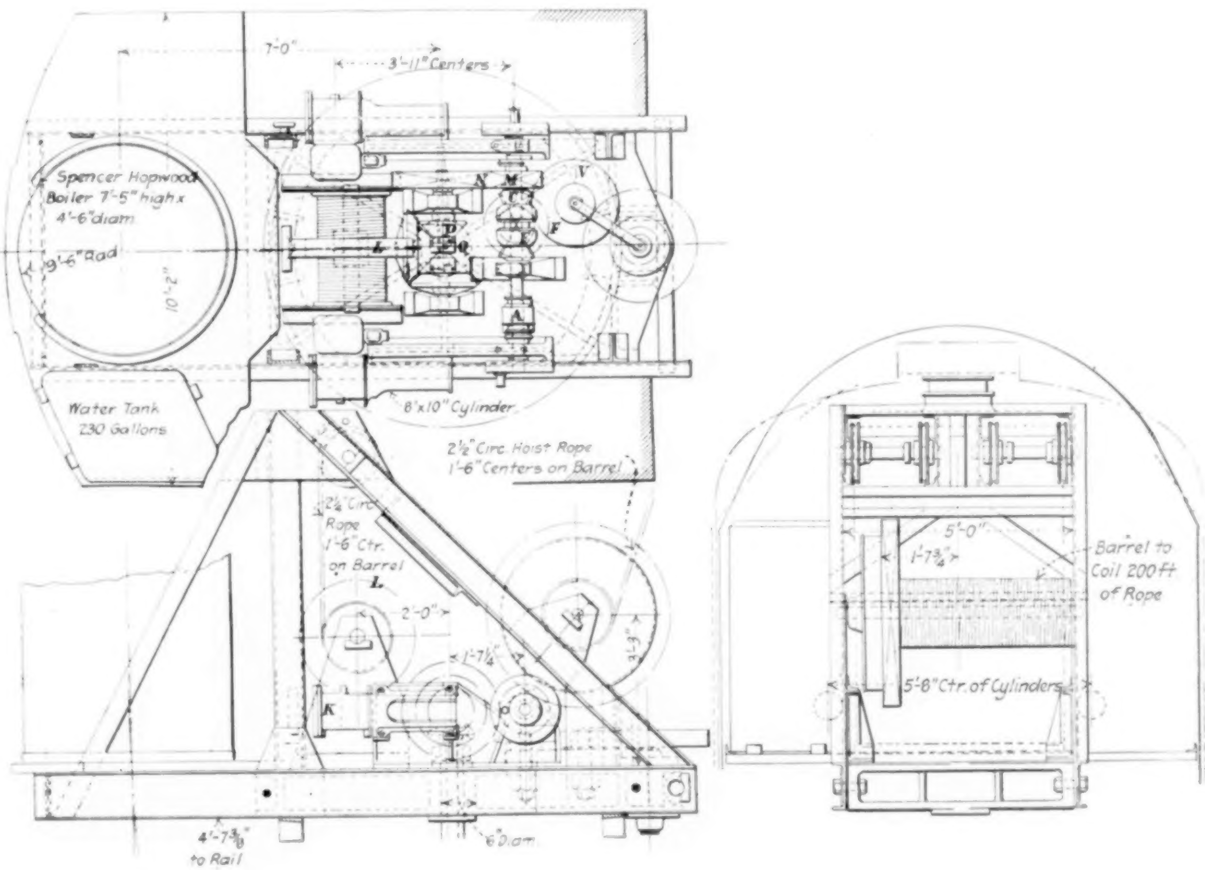

Fig. 6 Arrangement of Gear of the Crane Shown in Fig. 5

and the gear ratios of the headstock provide for cutting 342 different pitches, there being 167-in. pitches and 175 millimeter pitches. These different pitches are obtained by shifting the handles or levers and without changing any gear; and if other gears are inserted an entirely different series of 342 pitches may be obtained. The maximum pitch is 12 in. The pitches are divided into a large series and a small series. The latter, which is for general use, is obtained when the lead-screw is driven from the spindle in the usual manner. In the small series there are 37-in. pitches and 37 millimeter pitches. The large series is obtained when the lead-screw is driven from the driving pulley through the headstock gearing.

The lathe may be used for cutting worms intended for worm-wheels based on the module system. (The module of a gear is equal to the pitch diameter in millimeters, divided by the number of gear teeth.) With eleven change-gears, 69 module pitches may be obtained, having a range of from 0.75 to 60.

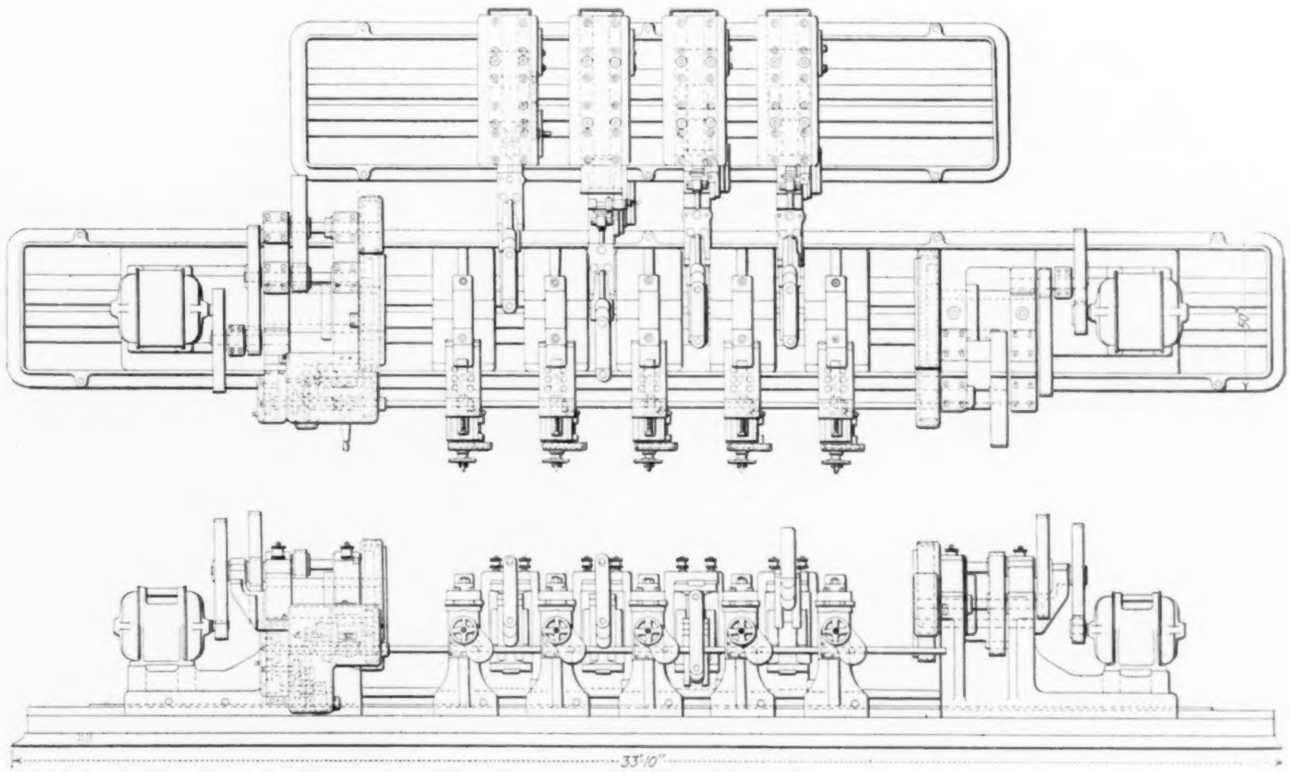

FIG. 7 DETAILS OF CRANK-SHAFT LATHE

The cross-feed screw of this lathe is connected to the feed-rod, or metric lead-screw, with gearing, so that spiral grooves may be cut on a plane or flat face; as, for example, when making the scroll of a chuck. There is a fixed ratio between the movement of the cross-slide and that of the carriage. For instance, on one lathe if it is geared for ½-in. pitch with the inch screw, and 8 mm. pitch with the millimeter screw, a spiral of 4 mm. pitch will be obtained, the cross-slide moving half as fast as the carriage when using the metric screw. By means of a special device, the carriage may be moved automatically along the bed while the spindle is stationary. (*Machinery*, vol. 26, no. 1, September 1919, pp. 59, *d*)

MEASUREMENTS AND TESTING

Advance Publication of an Investigation by the U. S. Bureau of Standards

PHOTOELECTRIC SPECTROPHOTOMETRY BY THE NULL METHOD, K. S. Gibson. In connection with the color standardization work of the National Bureau of Standards (I. G. Priest, The Work of the National Bureau of Standards on the Establishment of Color Standards and Methods of Color Specifications, Trans. I. E. S. XIII, p. 38, 1918) it is desired to have available a number of independent methods of making spectrophotometric determinations, especially in the visible part of the spectrum; for it is generally admitted that the fundamental basis of color specification is spectrophotometry. To supplement the other methods at present in use at the Bureau and especially to overcome the well-known uncertainty of measurements by these other methods in the blue and violet, the author in 1917 was given the problem of developing a method for accurate and convenient photoelectric spectrophotometry suitable for routine determinations. This was especially desirable for the measurement of spectral transmission. The sensitive potassium-hydride photoelectric cells now on the market (made by Kunz) when used with an incandescent lamp and a glassdispersing prism, give a maximum response usually near 460 millimicrons, and are thus very suitable for the purpose. The making and assembling of apparatus was completed in April, 1918; and since that time it has been in continual use, being very satisfactory as to speed of operation, ease of keeping in working condition, and accuracy of measurement.

In the null method as used, two photoelectric cells and the proper batteries are connected in a sort of Wheatstone bridge arrangement (F. H. Richtmyer, Phys. Rev. (2), VI, p. 66, 1915), with the electrometer as the indicator. Radiant energy from a 600-watt Mazda C moving picture lamp, after dispersion through a hilger constant deviation spectrometer, is incident upon one of the photoelectric cells. Radiant energy from a 14-watt Mazda C lamp is incident on the other photoelectric cell. The photoelectric currents generated in the two cells by the radiant energy from the two lamps tend to nullify each other so far as charging the electrometer is concerned; and by proper adjustments, the two currents may be made exactly equal, the zero motions of the spot of light from the electrometer indicating the balanced condition.

Measurements of the spectral transmission of a specimen are made by observing at any desired wave length the distances of the

600-watt lamp from the spectrometer slit necessary to obtain a balance of the electrometer with and without the specimen in position, all other factors such as slit widths, currents, etc., being kept constant. The ratio of the squares of these two distances respectively is the transmission. By this use of the null method all errors are eliminated, as well as the necessity of any kind of calibration, in connection with the relation between photoelectric current and incident radiant power, with the dark currents through the photoelectric cells, and with electrometer deflection methods.

The accuracy has been tested in various ways, chief of which are the measurements of rotating sectors of known transmission and comparisons with values obtained by other methods. It is considered that the uncertainties of values obtained from 410 to 550 millimicrons, inclusive, are not greater than 0.01 for any values of transmission between 0.00 and 1.00 and not greater than 0.003 for transmissions between 0.00 and 0.10. Beyond these wave lengths just given, as far as 390 and 600 millimicrons, inclusive, the uncertainties of measurement are not greatly increased, being at 390 and 600 not more than twice as great as throughout the better range. Measurements can be made from 380 to 650 millimicrons.

The apparatus has also been used for the measurement of spectral diffuse reflection relative to that of a standard such as magnesium carbonate, and is adapted to the measurement of the relative distribution of radiant power of two sources, to the measurement of fluorescence, and to extension into the ultra-violet if quartz parts instead of glass were used. (*Abstract of Scientific Paper* No. 349, *U. S. Bureau of Standards, dA*)

MECHANICS

Mathematical Investigation Abstracted from a Japanese Publication

The Stability of Long Struts of Variable Section, Prof. Akimasa Ono. The writer considers the determination of critical loads for long struts of variable section, in particular a long strut fixed at one end and free at the other tapered end. Furthermore, the same calculations may be applied to the case of a strut symmetrically formed about the middle and with tapered ends free to bend, in which case, however, either half of the strut must be taken separately.

The calculation is based on the assumption, as in the deduction of Euler's formula, that the axis of strut is quite straight, the material is homogeneous, the loading takes place without eccentricity and, moreover, the length of the strut is sufficiently long. Next, the cross section is supposed to vary in such a manner that the least moment of inertia is proportional to a certain power of the distance from the free end, where the axial thrust acts on the strut and the corresponding axis of reference lies always in a plane. Then the bending takes place in one plane and the differential equation to the elastic line is of a standard form whose solution can be readily written down. This being done the critical load may be determined with due regard to the end conditions, and the result thus obtained may be applied to find the least volume of struts for the same load and height.

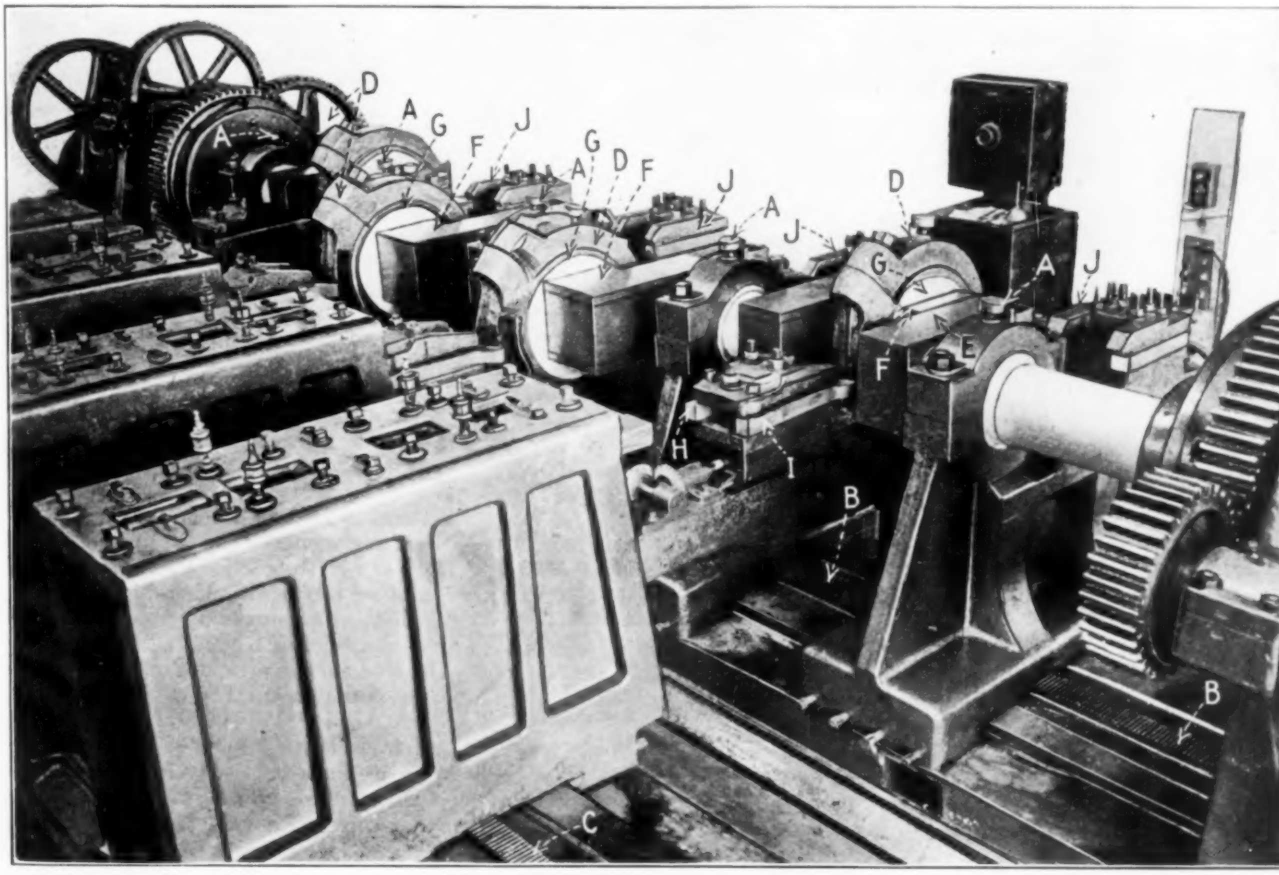

Fig. 8 The Machine with a Large Crankshaft in Place

In this connection, the author states that Professor Aichi has also deduced a formula based on the same principle as stated above, but obtained the results expressed in a form different from that obtained by the present writer owing to the difference in the expressions for the root of Bessel's function.

The author obtains the following expression for the critical load on the strut

$$P = \left(1 - \frac{n}{2}\right)^2 z_1^{\,2} \frac{EI_1}{l^2}$$

where P is the end thrust on the strut, E the modulus of elasticity, I_1 is the moment of inertia of cross section, n a numerical constant, l the distance between a plane at which the strut is fixed and the free end, and z_1 is given by

$$z = \frac{a^{1/2}}{1 - \frac{n}{2}} x^{1-\frac{n}{2}}$$

where a is given by

$$\frac{Pl^n}{EI_1} = a \text{ (constant)}$$

The author gives a numerical example by means of which he shows the laws of variation of the constants.

He also gives equations expressing the volumes of struts and shows that all other conditions being assumed to be equal, except the form of rods, the volumes of tapered and prismatic struts. V and V_0, respectively, are in the ratio

$$\frac{V}{V_0} = \frac{1}{n+2} \times \frac{\pi}{\sqrt{c}}$$

where both n and c are constants. (In another part of the paper it has been shown that the coefficient c varies in accordance with the certain law with the variation of the coefficient n).

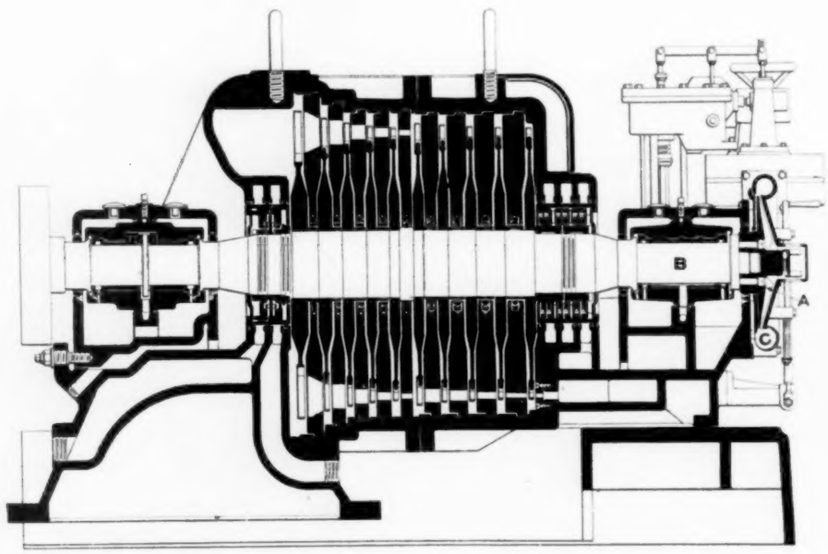

FIG. 9 APPLICATION OF FAN IMPELLER TO THE TURBINE SHAFT

The following summary of the paper is given by the author:

(1) The assumption that the amount of inertia varies as the n-th power of the distance of the section from the free end, leads to the simple formula for the critical load.

(2) For a given rod, whose cross section varies in any assigned manner, the present formula may be used to judge the range, in which the critical load lies.

(3) With proper choice of form, the volume of struts may be reduced to a limit about 13 per cent less than the uniform rod of similar sections for the same load and height.

(4) When $n = 1$, the volume is nearly least, though the tapering is a little over. In this case the stress is a maximum at the distance equal to about one-third of the length of the strut from the tapered end.

(5) An empirical formula may be conveniently used for finding the first root of Bessel's function $J_s(z)$ in a small range of s. (*Memoirs of the College of Engineering, Kyushu Imperial University*, Fukuoka, Japan. vol. 1, no. 5, 1919, pp. 395-406, 4 figs., *mt*)

POWER GENERATION (See Fuels and Firing)

POWER PLANTS

Description of a New Type of Governor for Steam Turbines

PNEUMATIC STEAM TURBINE GOVERNOR. Description of a new type of pneumatic governor designed by the Ridgway Dynamo and Engine Company, of Ridgway, Pa. Air replaces the metal balls or weights as well as the conneting linkage levers, etc., between the centrifugal elements and the valves. It is described in the following manner in an interesting article in *Power*:

Referring to Fig. 9, a small fan impeller A bolted to the end of shaft B is enclosed by the fan housing C and generates an air pressure of about 12 in. of water at 3600 r.p.m. This air pressure acts on the under side of two light aluminum pistons D and E, Fig. 10, forcing them upward. This movement is opposed by the spring F. At the upper end of the piston rod G the lever H operates the pilot valve I, which admits oil to and from the cylinder J, the piston K of which operates the main inlet valves L, M, N, N being an overload valve. The spring O is for the purpose of closing the main valve in case the oil pressure should fail for any reason.

A synchronizing motor P is for adjusting the speed from the switchboard. Q is a worm on the motor shaft and R is a wormwheel which engages with the handwheel S by means of pin T. The speed may, therefore, also be adjusted by hand with the sheel S. An electric contact U is for the purpose of breaking the circuit in case the motor is run too far in either direction.

The hub of the fan impeller A has a spring bolt V, for operating the emergency trip. In case of overspeeding this bolt V strikes the hair trigger W, releasing the hammer X, which in turn strikes the main latch Y a blow, releasing the rod Z which, due to the spring A^1 closes the butterfly valve B^1 in the steam line. Handle C^1 is in the form of a loose toggle, the lost motion of which permits some movement of Z before a movement of the bell crank takes place; thus the inertia of Z under movement is used to start the butterfly below the throttle valve.

The pneumatic governor has many advantages. The only running part is a plain disk, with vanes on the side of it, which is bolted to the end of the shaft. Air forms the connecting medium between it and the other moving parts, and these move only on a change of speed due to a change of load. The small pilot valve I and piston K move in oil and should therefore last indefinitely. The governor as a whole is simple and little subject to wear. The only work to be performed by the air pistons is to operate the small $\frac{5}{8}$-in.-diameter pilot valve, which is balanced and floats in oil. The air force on these two pistons is about 150 lb. The pneumatic action is therefore quite powerful and reliable. The air pressure generated by the fan is as the square of the speed, and slight change in speed, therefore, is quick and effective in its action.

Oil is used in the power cylinder J because it acts like an oil dashpot, preventing jumping, overtraveling or hunting of the main valves, and at the same time it insures long life to these parts. Oil for the operation of the governor is supplied from a branch off the oiling system for the bearings. The conditions of atmosphere may slightly change the speed of the turbine, but these are so slight as to be negligible and need not be considered. (*Power*, vol. 50, no. 8, Aug. 19, 1919, pp. 300-301, 2 figs., *d*)

Suggested Standard Form for Reporting Economizer Tests

PERFORMANCE TESTS OF ECONOMIZERS, B. M. Baxter, Mem.Am. Soc.M.E. The author suggests a standard method of making and reporting economizer tests.

The important factors entering into the design of an economizer are the rate of heat transfer from the gases to the water, the draft loss and to some extent the efficiency. The first of these determines the heating surface necessary for the desired results; the second, the arrangement of the heating surface and the amount of free area between the tubes necessary to be provided to avoid undue resistance to the flow of the gases, or expressed in another way, loss of draft; the efficiency affects the performance

in that it determines the percentage of available heat of the gases which can be counted upon to be absorbed by the feedwater. Furthermore, the rate of heat transfer from the gases to the water is materially affected by the velocity of the gases through the economizer. Hence, it is essential that as high velocity of the gases be obtained as the conditions of the installation in question will permit, but the higher the gas velocity the greater the draft loss, and it is in connection with the calculation of draft loss that present knowledge of economizer performance is deficient.

The author suggests the following form for reporting economizer tests:

1 Date of test
2 Type of economizer, parallel flow or staggered tube
3 Length of tubes
4 Number of tubes per section
5 Number of sections
6 Square feet of heating surface, builder's rating
7 Square feet free area between tubes
8 Duration of test in hours
9 Total amount of water passed through economizer
10 Average rate of flow of water through economizer, lb. per hour
11 Average temperature of water entering economizer, deg. fahr.
12 Average temperature of water leaving economizer, deg. fahr.
13 Average temperature rise of water in passing through economizer
14 Average temperature of gases entering economizer, deg. fahr.
15 Average temperature of gases leaving economizer, deg. fahr.
16 Average analysis of gases: carbon dioxide, per cent; carbon monoxide, per cent; excess oxygen, per cent
17 Pounds of flue gas per hour passing through economizer
18 Average velocity of gases through economizer
19 Average draft at entrance to economizer
20 Average draft at exit from economizer
21 Average draft drop through economizer
22 B.t.u. transmitted per hour per sq. ft. of heating surface
23 Mean temperature difference between gases and water
24 B.t.u. transmitted per hour per sq. ft. of heating surface per degree mean-temperature difference (Coefficient of heat transfer)
25 Specific heat of gases (State whether assumed or calculated)
26 Efficiency (Ratio of heat absorbed by water to heat lost by gases)
27 Draft loss per section

(*Power*, vol. 50, no. 8, August 19, 1919, pp. 299-300, *t*)

PUMPS

Water Pumps of the Drainage Station at Codigoro. Part of an article describing the whole installation. The general construction of the pump appears in Fig. 11. The pump is designed for a delivery of 8000 litres (2113 gallons) per sec. and the rotor is so located that even at the lowest level of the water the pump can be started without priming. The water itself is of an exceedingly corrosive nature attacking both wrought iron and steel. Hence, the use of these materials has been carefully avoided and where inevitable the metal parts were protected by bronze bushings or sleeves.

The weights of the rotating parts of the pump are taken up in starting by a roller bearing located under the crankshaft bearing. During the operation of the pump, however, the load on the roller bearing is entirely taken up by a pressure oil bearing, the construction of which appears from Fig. 12.

The suction and pressure chambers are so proportioned that in each group these chambers may be emptied without thereby affecting the operation of the other groups. For this purpose, protective devices have been installed on the suction chambers so that they could be kept empty during repairs or cleaning. A special centrifugal pump is provided to take care of the emptying of these chambers. (Part of serial article in *Schweizerische Bauzeitung*, vol. 74, no. 3, July 19, 1919, the part abstracted here being on pp. 30-31, 7 figs., *d*)

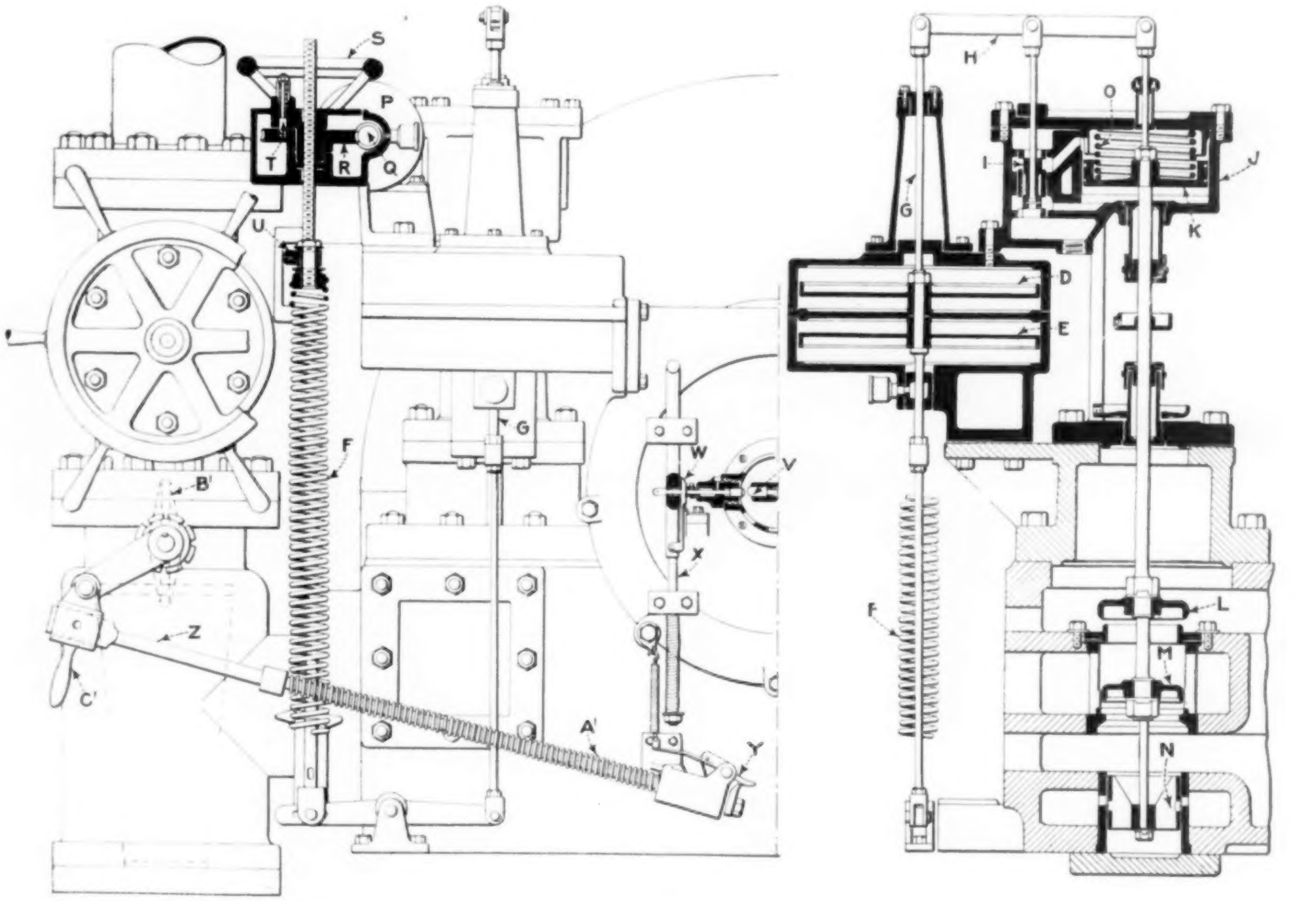

Fig. 10 Details of the Pneumatic Steam-Turbine Governor

RAILROAD ENGINEERING

PRODUCTION OF CORRUGATIONS ON RAIL SURFACES. (F. Märtens, *Organ fur die Fortschritte des Eisenbahnwesens*, April 15, 1919). This well-known and troublesome phenomenon is discussed in detail. Faults in rail material and manufacture have their influence, the composition and structure of the steel can either facilitate or hinder corrugation; but the essential causes are mechanical, and may be induced by rough surface left on the rail by defective rolling, or on the wheel by excessive lathe vibration during turning.

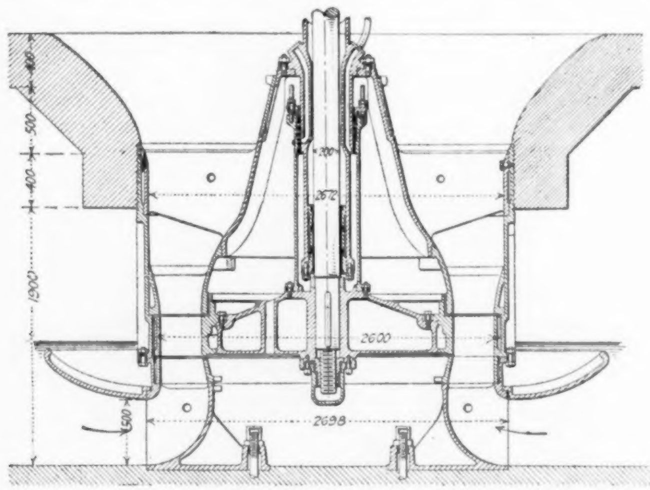

FIG. 11 CROSS SECTION THROUGH THE AXIAL PUMP AT THE CODIGORO DRAINAGE PLANT

Especially on hard and non-resilient track, oscillations are set up in running by these causes, which increase with increase of speed. Both rail and rolling stock are set in oscillatory motion; the wheel ceases to roll uniformly, and partly slips, partly jumps along the track. The wheel positions constantly alter, transverse axle movement takes place, and friction from side to side as well as in the line of travel takes place upon the rail.

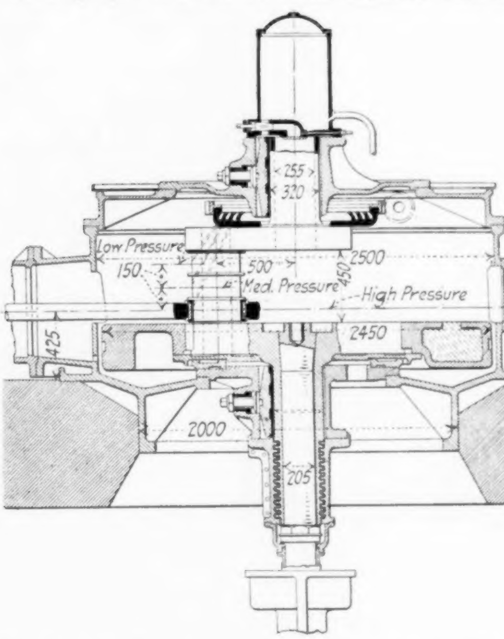

FIG. 12 SECTION THROUGH THE BEARINGS OF THE PUMP SHOWN IN FIG. 11

By these forces the original inequalities are hammered flat, and these places become harder than the other parts of the rail, the unequal hardness leading to uneven wear, and the development of further corrugations. Rough-surfaced rails should therefore never be used.

To prevent lateral movement of the wheels on the rails, the causes of which are explained in detail, it is necessary to see that uniform wheel diameter is maintained. It is further recommended to lay the rails with the surrfaces inclined inwards.

The great importance of the condition of the rail joints is insisted upon; the defective joints are fertile initial causes of corrugation.

The influences of braking and speed acceleration are dealt with, and results of the author's observations described.

Corrugation is not so likely to take place at lower speeds and with resilient track.

A number of photographs and a diagram are given, showing the microscopic structure of the steel in the troughs and on the peaks of the corrugations, and the shape and arrangement of the latter.

Remedies are discussed, and the importance is indicated of finding the relation between the rates of pulsation of the rails, trackwork, and rolling stock, so that by alterations of construction these may be made to neutralize each other, when the corrugations will, in time, disappear.

The question of rail joints is dealt with. The vertically interleaved joint would, theoretically, be the ideal one, but in practice such joints have been found to be dangerous through their tendency to open and spread. An improvement in the horizontal type of overlapping joint is suggested as a fruitful line of experiment, though it is admitted that these also have hitherto proved too weak in service.

In spite of the low speeds usual on street tramway lines, corrugation is a frequent and obstinate trouble in these also. The corrugations are usually removed by hand or by special planing machines, but quickly reappear.

Corrugation can only be remedied by an analysis of its causes and the adjustment of these to counteract each other, or by such an improvement in rail material as will defy the action of these causes altogether. (*Technical Supplement to the Review of the Foreign Press*, vol. 4, no. 4, August 19, 1919, p. 122, no. 5857, *t*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

A triple-motored monoplane of the seaplane type, with twin floats, is being constructed at the Los Angeles factory of the George D. White Company. This monoplane is intended for use in a trans-Pacific voyage from Los Angeles to Shanghai, and will stay at San Francisco, Victoria,, Sitka, Unalaska, Petropavlovsk, and Yokohama, making in all a 7000-mile trip.

The dimensions of the machine are as follows: wing spread 82 ft.; length overall 39 ft.; height to top of fuselage, 9 ft.; weight empty, 3700 lb.; weight with crew and fuel for the Pacific flight, 7900 lb.; total horsepower, 660, generated by three Hispano-Suiza engines. Two 180-hp. engines are located, one on each wing, on each side of the body. The third engine, 300 hp., is installed in the nose of the fuselage as in single-motored aeroplanes.

Either the two 180's or the one 300-hp. engine will be used, but all three are not to be used simultaneously. A speed of 110 miles an hour will be given by the 300-hp. engine. By having approximately the same amount of power in reserve as is being used, it is expected that the possibility of failure will be lessened. At the start the two 180's will be used with the 300-hp. engine in reserve. After running a number of hours the central engine will be switched on and the two smaller engines shut off. This method will be followed throughout the entire flight in order to allow the engines to rest and also to allow the engine expert to make an inspection and the necessary minor adjustments. New spark plugs can be installed, carburetor adjustments made, ignition troubles overcome, or other minor requirements which, under ordinary conditions, mean motor failure and an interrupted flight. From *Aerial Age Weekly*, August 11, 1919.

Recent Work of C. E. Johansson

C. E. Johansson, the Swedish gage manufacturer, whose invention and production of the famous Johansson gage blocks has constituted one of the important steps in the development of interchangeable manufacturing, is now in this country and exhibits some exceedingly interesting measuring and gaging devices of almost unbelievable accuracy. Prominent among these is a set of 11 gage blocks, the opposite surfaces of which Mr. Johansson assures are parallel and accurate within 1/1,000,000 in. In other words, he states, and shows his gages as evidence, that he not only is able to measure to this degree of accuracy, as others have done, but actually to produce surfaces having this remarkable accuracy. These blocks start at 1/10 in. in thickness and increase

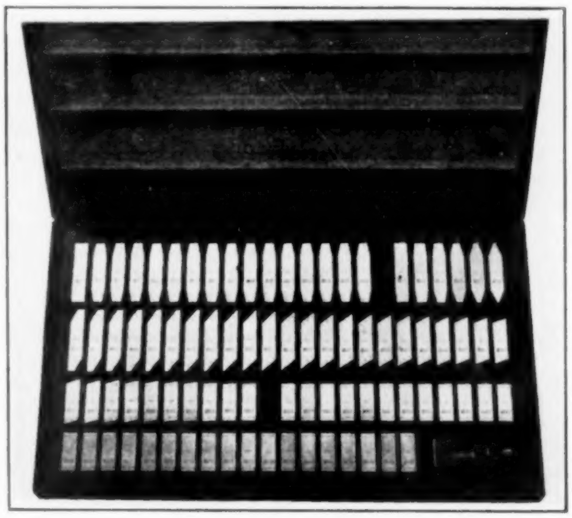

Fig. 1 Set of Angle Gage Blocks

by increments of 0.000001 in. up to a thickness for the last block of 0.00010 in.; that is, the distance between the parallel surfaces of the last block of the series of 11 blocks is only 1/100,000 in. greater than in the first block.

Even more striking is a large set of angle gages shown in Fig. 1. The adjacent edges of the successive gages form angles increasing by increments of one minute until 60 minutes or one degree is reached; after which they increase by increments of one degree up to 90 degrees, thus completing the first quadrant of the circle. A third group then divides the last degree of the quadrant into minutes. By means of these gages any angle can be obtained to a refinement of one minute. By their use, for example, screw threads can be measured on a line parallel with the center line of the screw as well as normal to the screw spiral.

A rigid test of the regular Johansson blocks is made by Mr. Johansson with a new type of micrometer in the screw casing of

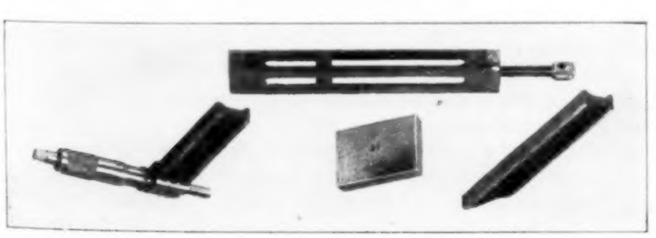

Fig. 2 Parts of Adjustable Micrometer Used in Combination with Gage Blocks of Different Sizes

which is a row of standard disks spaced definite distances apart, by means of which the micrometer screw can be set at certain definite distances from the anvil; and when so set the Johansson block corresponding to the reading of the micrometer can easily be slipped between the measuring points and held suspended there by the almost imperceptible friction of the surface. Repeated trials with different blocks and different settings showed not the slightest variation from standard by either blocks or micrometer —truly a remarkable test.

The parts of one of a series of micrometers of another type, in which gage blocks are used to set the instrument for measuring a piece of any desired size, are shown in Fig. 2. There is a holder in which the several parts are clamped and held while measuring. The micrometer head is slipped in at one end and a bar constitut-

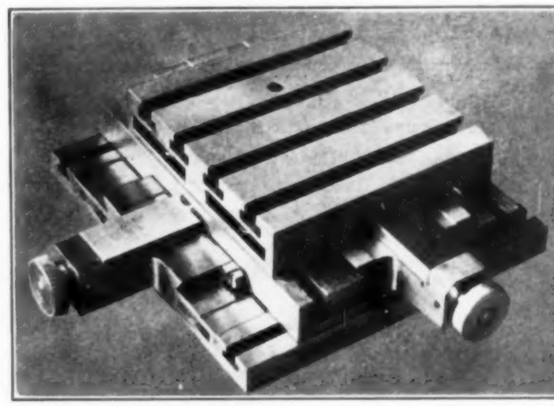

Fig. 3 Compound Dividing Plate Used in Combination with Gage Blocks

ing the anvil at the other; while between them is inserted a gage block used as a distance piece against which the two other parts are clamped by the screw at the end of the holder.

In Fig. 3 is a compound table or dividing plate for laying out

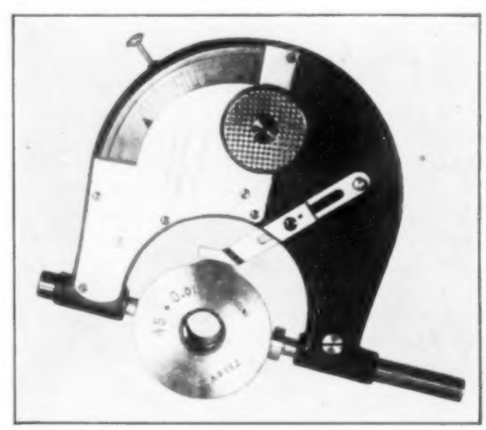

Fig. 4 Rapid-Indicating Snap Gage

jigs or other work requiring the accurate location of holes or definite points. It will be noted that the table itself is moved either parallel or at right-angles to the slots of the baseplate in the usual way by means of the adjusting screws; but that the location of the plate in either direction is determined by the insertion of gage blocks between fixed surfaces and the edges of the two moving parts of the table. By bringing these edges firmly against the blocks the desired setting is obtained with great precision.

In Fig. 4 is a rapid indicating snap gage measuring in minute fractions of a millimeter. The pointer will be seen in the upper left-hand part of the gage, as it appears in the engraving, and after the measurement has been taken and read the pointer is returned to zero, ready for the next reading, by pushing the projecting button seen projecting from the edge of the gage.

Announcement has been made of scholarships in the various universities and colleges in Pennsylvania now available for ex-service men. Special short courses, reduced rates, and loan funds are also being offered, and every effort is being made to assist those who desire a college education.

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

The printing industry in New York City is threatened with the most serious strike in the history of the industry, to occur October 1. While it is hoped, and by many expected, that matters will be adjusted by the time this number of Mechanical Engineering is issued, the immediate result has been congestion in the printing offices of the city which has caused the omission from this number of certain matter, particularly relating to the work of the Sections for the past year, which otherwise would have appeared. Whether difficulties will be encountered in the publication of the November and subsequent issues yet remains to be seen. This brief announcement, however, is made to our members so that in the event of the strike being called, they will understand that any delays which may occur are unavoidable.

The Annual Meeting

Following the plan of the meetings which have been called during the past few years, there will be a keynote session at the Annual Meeting on the Industrial Situation in Relation to Present Conditions, with papers on several topics, including wage payment, rights of workers, systems for mutual control of industry and profit sharing. This is a continuation in a broader field of the session on Industrial Relations held at the Spring Meeting at Detroit which evoked so great an interest and resulted in a vote by the meeting in favor of continuing the discussion at the time of the Annual Meeting.

There was so great interest at Detroit, also, in the subject of fuels, and particularly pulverized fuel, that the subject will again come up at the Annual Meeting for further discussion. It is proposed, also, to have a session on Appraisal and Valuation Methods.

The Sub-Committees on Machine Shop and Foundry Practice, Textiles and Gas Power are planning sessions. The Foundry Sub-Committee has arranged for papers on castings of various metals and bronzes, and die castings. The Textile Committee will devote its attention this year to education for the textile industries in our technical schools. There will be the usual miscellaneous technical papers.

At this meeting, following as it does the signing of the armistice and the return of our troops from abroad, the tendency will be to deal with subjects which concern the forward movement of the nation and the engineer in the work of building up the industries and putting the nation on a stable basis as regards labor and industrial conditions. At the same time, the past will not be forgotten. There will be the memory of those of the Society who have given their all in the service of the country and the winning of the condition of democracy which all hope may eventually obtain. As a testimony to these, there will be a memorial service with suitable exercises during the period of the meeting.

International Pipe Threads Hearing

The Committee on International Standard for Pipe Threads, of the American Society of Mechanical Engineers, is to hold a public hearing in the Engineering Societies Building, New York, on October 2, 1919, at 10:30 a. m. The Committee is to meet at this time to discuss and prepare resolutions which are to be presented at the next meeting of the Commission for an International Standard Pipe Thread, which is to be held in Paris, November 7th. As it is the desire of this committee and the Society that these resolutions express the opinions and best judgment of the American pipe industries, they will welcome to this meeting representatives of all associations and manufacturers interested in this important branch of engineering.

Final Hearing of National Screw-Thread Commission

The last public hearing in America of the National Screw-Thread Commission on national screw-thread standards will occur on Monday, October 6, 1919, at 10 a. m., in the Engineering Societies Building, New York. The engineering bodies interested and the industries manufacturing and using screws will meet and give full and final consideration to the report. A general invitation is issued to all who are interested to attend, and it is hoped that a large number will be present.

Labor Problem Discussed at New York

Industrial Unrest and the Engineer was the subject discussed at a largely attended meeting of the New York Section of the A. S. M. E., the first to be held this fall, in the Engineering Societies Building on September 17. The speaker of the evening was Dr. William M. Leiserson, formerly Chief, Division of Labor and Administration, Working Conditions Service, U. S. Department of Labor.

The circular of the meeting announced the address as a "straight from the shoulder talk," and the speaker lived up to expectations. He gave an admirable review of labor conditions and difficulties in the very early days in Europe and in this country since the beginning of the last century, showing how these were first allied with religious conditions, second with political conditions and finally, at the present time, with industrial conditions. He made the statement that current labor unrest as evidenced by strikes is not relatively greater than at some other periods in our history, in spite of its present huge proportions and widespread distribution.

He analyzed the various classes of strikes, showing that those which occurred independently of our large organizations are less influential in the labor problem as a whole, even where extreme radicalism is displayed, than well-organized, conservative movements on a large scale, as for example, by the railroad employees of the country. With his historical background as a basis, he discussed causes and possible remedies of our industrial unrest in which he emphasized the need for consideration of the public welfare rather than of class interests.

In referring to unions of municipal and federal employees, he said that undoubtedly the American public was not willing to sanction their affiliation with a central body like the A. F. of L., but that he persoanlly could see no serious objection to such affiliation. This remark gave the cue to the first speaker on the

list to discuss the address, Mr. Richard H. Rice, Acting Manager of the General Electric Company's plant at West Lynn, Mass. Mr. Rice said he had just come from Boston and knew what the conditions were because of the police strike there, and that he was unalterably opposed to any division of allegiance on the part of public employees, to which the audience responded with unqualified cheers of approval.

During the discussion, a report was presented by the New York Committee in charge of this meeting, which contended that the engineer is the only one who speaks the language of both the capitalist and the workman, and that out of his ranks must come the remedy—a remedy which must be nation-wide in its purpose, as have been the solutions of past crises in this country, such as that of taxation without representation during the Revolutionary War, and preservation of the union during the Civil War.

The discussion lasted until well past twelve o'clock, at which time, fortunately, the chairman was obliged to catch his last train for home and closed the meeting; but the interest was so great that it was voted unanimously to continue the subject at a later meeting. As a whole, the discussion failed to focus on any definite policy, because of the tendency to emphasize individual experiences and interests, rather than a constructive policy.

Joint Mid-Section Meeting

Eight Sections to Participate in Two-Day Session at Indianapolis—October 24-25

The Indianapolis Section has invited the Sections at Birmingham, Chicago, Cincinnati, Cleveland, Detroit, Milwaukee, and St. Louis to join with it in conducting a two-day session on Friday and Saturday, October 24 and 25.

The program is being developed along the following outline:

Headquarters—Claypool Hotel

Friday, October 24

9:00 a.m.	Registration Hotel Claypool
10:00 a.m.	Council Meeting
10:00 a.m.	Meeting of Several Committees
10:00 a.m.	Visit to Indianapolis Industries
12:30 p.m.	Luncheon—Claypool Hotel
2:00 p.m.	Professional Session on "Industrial Unrest"
6:30 p.m.	Banquet and Entertainment at Claypool Hotel

Saturday, October 25

9:30 a.m.	Professional Session on "Research"
9:30 a.m.	Visit to Indianapolis Industries
12:00 m.	Automobile Trip to various interesting points about the City
1:00 p.m.	Canoe Club for luncheon, continuing trip thereafter until 4:30 p.m.

Sunday, October 26

For those remaining over Sunday an automobile trip to Turkey Run or Wyandotte Cave has been proposed.

Quarterly Joint Sections Meetings

This meeting is being planned with an aim to secure two such Quarterly meetings to be held alternately with the Annual and Semi-Annual (or Spring) meetings. The Indianapolis meeting will compare favorably with the recent Spring Meetings of the Society and warrants the attendance of a large representation of the membership. The central location of Indianapolis should secure a registration of one thousand members and their friends. Members should advise the Secretary of the Society of the names and addresses of any engineers whom they would like to have formally invited.

Every member of the Society is, of course, expected to attend this meeting, and those who avail themselves of the opportunity are assured a meeting which will be enjoyed by all, and which will be good and lively throughout the entire two days. The many attractions of Indianapolis will add to the interest.

Ninth Volume of Condensed Catalogues

The ninth annual volume of The American Society of Mechanical Engineers' Condensed Catalogues of Mechanical Equipment, with General Classified Directory and Engineering Data Section, is now being printed and will be ready for distribution on October first if conditions in the printing trade remain normal.

It is with much pleasure that the Society records the continued satisfactory development of this volume. Five hundred and five firms are this year represented by publication of catalogue data, as against four hundred and fifteen last year.

There are six hundred and sixty-nine catalogue pages, and the general Mechanical Equipment Directory, in which all eligible manufacturers are entitled to listing of their products free of charge, within reasonable limits, has been further extended this year.

The Engineering Data Section is continued and contains the current data from the Society's publications, the Transactions and Mechanical Engineering, as well as other useful information concerning the standards issued by the Society, and a list of papers published in the Transactions since the beginning of the Society's activities.

To the Members of the American Society of Mechanical Engineers

A committee has been organized to assist in securing employment for blind and other disabled soldiers and sailors who have been specially trained for useful pursuits by the Red Cross Institute for the Blind at Baltimore. The Institute is educating the blind soldiers along certain definite lines, so as to train them in trades and occupations, and thus enable them to become useful and self-supporting members of the industrial community. In time this service will be extended to include blind civilians as well as soldiers and sailors.

Individuals so trained will be competent to take their appropriate places in industry, and will in no sense be subjects for charity. They will only ask that they be given equal opportunities with those not so handicapped.

Now is the time to inaugurate a movement looking toward the teaching and employment, not only of disabled soldiers, but also of crippled civilians. To train and use men and women, who from one cause or another have been partially disabled, will be an economic gain, as well as a social duty, and will add a valuable asset to our national ledger.

The committee appeals to you, as a member of this Society and as employers of labor, to lend your assistance in this important work by studying the problem as it affects your establishment, by finding employment for such disabled workers as may come to you and by endeavoring to develop a sympathetic attitude in your community.

We further hope that you will give suitable publicity to the work being done by the American Red Cross for the blind soldiers, sailors, and marines. News items and editorial comment in your local papers will help in this. The Red Cross Institute will gladly furnish any needful information.

May we not count on you to give this subject earnest consideration and to assist the committee by your coöperation and by such counsel as your experience dictates? The committee will appreciate any response which you may see fit to give.

C. H. Benjamin,
Chairman, Committee on Rehabilitation of the Blind.

That the Blind May See and Work

In the above letter Dean C. H. Benjamin, Chairman of the A. S. M. E. Committee for the Rehabilitation of the Blind, makes an appeal to engineers to provide employment for the blind men of the army who have been trained for useful service at the Red Cross Institute at Baltimore.

It is gratifying to know at the outset that the number of the young men of the A. E. F. who lost their eyesight in the war is no greater than one hundred and twenty-five; and it is also gratifying to know that their training is under the direction of an en-

gineer, Mr. L. W. Wallace, a member of this Society, who is combining his knowledge of the industries with his qualifications as a teacher and as an engineer to give the soldiers a practical training of such a character that they may become capable wage earners. Mr. Wallace is conducting this work with enthusiasm, in full confidence of its successful outcome.

The men receive four distinct lines of training: (1) preparatory, (2) vocational, (3) in avocations, and (4) in recreation. All the men learn Braille, typewriting, English and self-expression and parliamentary law so that they may keep informed and be able to convey their ideas correctly and effectively by the written and spoken word. They learn the usual occupations taught to blind people, such as playing musical instruments, weaving, basketry, carpentry, etc., only to give the men a pastime. Their vocational work is much more serious and important. A careful study has been made of many of the operations in the industries to determine which of these can be performed without the use of the eyesight. For example, it has been found that certain operations in the manufacture of automobile tires, on the inside of the tire, can be done by the blind, and a group of blind men are expected to find employment in the works of the Goodyear Rubber Co. under the direction of a blind lieutenant who is already at the plant making a study of the work.

The training and education of these men of the army, while worthy as a direct accomplishment, has much greater significance than is generally understood. It is aimed to make the Institute a permanent institution for training blind civilians of whom there are estimated to be 80,000 in this country alone. If this training of the soldiers by scientific engineering methods is as successful as expected, it will constitute a great inspiration and a bright ray of hope to this great army of peacetime beings, and particularly to the young. All success to this great work which constitutes another example of the varied duties which an engineer may be called upon to perform in the practice of his profession!

Employers Plan National Organization

A national organization of employers, into a body to look out for managerial interests in the United States in the same way that the unions are protecting labor, was launched in Chicago during September by the Illinois Manufacturers' Association.

Charles Piez, Mem.Am.Soc.M.E., formerly with the U. S. Shipping Board, but now returned to the Link Belt Company, has been named as chairman of the committee for organization throughout the country. Other members of the committee are: Alba B. Johnson, president, Baldwin Locomotive Co.; H. H. Merrick, president, Chicago Association of Commerce; Thomas Creigh, Cudahy Packing Co.; and John M. Glenn, secretary, Illinois Manufacturers' Association.

The chief work of the new organization will be to make felt the wishes of the business interests that concern the welfare of the entire nation in Washington. The first steps of the organization committee will be to bring together trade bodies, chambers of commerce, and other groups of business men and impress them with the need of a national organization. Resolutions which deplore the spread of radicalism, urge a return to thrift and industry, and advise that a federation of employers be formed were recently passed by the recent "Our Country First" conference held in Chicago and have been sent out to business organizations all over the United States.

John M. Glenn is the originator of the idea of a national organization. He recently said: "Three million laboring men affiliated with the unions have made themselves heard in Washington. Manufacturers have found this out. This organization will do the same thing for the manufacturers."

Commenting on the situation, Charles Piez said: "Manufacturers are awakening to the fact that they must present their views to Congress collectively, if they are to get what is their due in the way of legislation. Labor has had the advantage while employers have been organized into comparatively small organizations. It must not be inferred that this federation is to be an anti-union body. We are not out to fight anyone. We intend, merely, to look out for the interests of business."

Employers organizations represented on the permanent committee are: Illinois Manufacturers' Association; Minnesota Employers' Association; National Conference of State Manufacturers' Associations; National Association of Manufacturers; Railway Business Association; Mississippi Valley Association; American Institute of Industrial Engineers; Railway Age; Ohio Manufacturers Association, and various associations representing different trades and classes of business.—H. T. L.

President Wilson's Conference on Capital and Labor

As announced in the daily press, President Wilson, before leaving Washington, wrote a letter to the presidents of several national organizations representing labor, farming, and financial interests, calling upon them to select delegates to the Capital and Labor Conference which he has called to meet in Washington on October 6.

The President's letter was addressed to Magnus W. Alexander (Mem.Am.Soc.M.E.), director of the National Industrial Conference Board, Boston; President Samuel Gompers, American Federation of Labor; President William G. Baker, Jr., of the Investment Bankers' Association, Baltimore; President J. H. Tittamore, American Society of Equity, Omro, Wis.; President Oliver Wilson, National Grange, Peoria, Ill.; President C. S. Barrett, National Farmers' Union, Union City, S. D., and President Homer L. Ferguson, Chamber of Commerce of the United States, Newport News, Va.

In his letter the President fixes the representation at the conference as follows: American Federation of Labor, 15; Chamber of Commerce, 5; National Industrial Conference Board, 5; farming organizations, 3; investment bankers, 2; selected by the President, 15. Total, 45.

The President stated the purposes of the conference to be:

1 To canvass every relevant feature of the present industrial situation.

2 To work out coöperatively a practicable method of association based upon real community of interest which will redound to the welfare of all the people.

A copy of the President's letter received by Mr. Magnus W. Alexander, managing director of the National Industrial Conference Board, was transmitted to The American Society of Mechanical Engineers as one of the members of the National Board. This was accompanied by a letter from Mr. Alexander to the Society asking for suggestions of men to nominate to the President, and urging the importance of a definite and constructive program for presentation at the conference at Washington. At the time of going to press the selection of names for recommendation is having consideration.

Free Coal?

In the Engineering Survey in this issue is given an abstract of an article in *Power* discussing low-temperature coal distillation. This article makes a statement, apparently well borne out by recent experiences, to the effect that a plant consuming 50 tons of coal or more per day of 24 hrs. and operating on a 24-hr. schedule, can, by adopting the comparatively inexpensive process of low-temperature coal distillation, secure enough by-products to pay for the cost of the raw material (coal) and have enough fuel left for its own use to generate all the power that it needs. Particularly would this be the case if this low-temperature process were combined with that of the by-product gas producer, such as the Mond, whereby ammonium sulphate might be recovered from the coal.

In other words, a plant operating under the above conditions would not only have its fuel free, but would materially conserve the supply of coal for other purposes. If future research and experience shows the process to be practicable, it is an extremely important development from two points of view.

In the first place, the majority of our public service utilities belong to the class of concerns consuming more than 50 tons per

day and operating on a 24-hr. schedule. They also belong to the class of concerns which were hardest hit by the rise in the cost of labor and materials, in particular the cost of fuel, and the result of low-temperature distillation of coal with its attending saving might help them to pass through an unusually bad business contingency.

But even more important is the promise of fuel conservation held out by the new development. What it amounts to really is an improvement of about 100 per cent in the utilization of the resources contained in our coal, and if the installation of a comparatively simple and cheap process may produce such a tremendous saving what greater promises does the near future hold out to us.

Post-Graduate Course in Gasoline Engine Design

The design of gasoline engines for automobiles was a comparatively simple matter. An automobile engine nine times out of ten operates at less than overload and at full load is usually relieved by the use of a gear shaft. If an automobile engine meets a load it cannot handle it stalls and the driver takes it in a friendly spirit.

Moreover, an automobile engine operates under fairly uniform conditions of air pressure and when these conditions change materially, as in taking a car from a sea-level country to high altitudes, special carburetor adjustments for which sufficient time is allowed are considered to be in order and are made without objections.

With the aeroplane engine the case is different. It is many times as powerful as an automobile engine; in fact, as regards power output an aeroplane engine just about starts off where the automobile engine stops. Coupled with this greater power output is the necessity of keeping the weight of the aeroplane engine to the lowest possible limit consistent with safety, which means an immeasurably finer design of every part and a much deeper knowledge of the strains of the parts and the physical properties of the materials used. To a certain extent, however, this disadvantage is counterbalanced by the fact that at least the question of cost did not come in as a material consideration in the design of aeroplane engines.

The aeroplane engine is further supposed to run all the time at or near full load, which, of course, stresses the engine far more than the more leisurely operation of an automobile engine.

A new requirement brought about by the war, and which presented a difficult problem for the engine designer to solve, was to produce an engine capable of delivering a high power output at high altitudes. It was attempted to solve this problem in three ways, the first and most obvious of which was for the flier to carry a supply of oxygen, either as gas compressed in cylinders or in the form of some material having a very high oxygen content. This was the method used by Captain Schroeder at McCook Field, Dayton, Ohio, last summer, in the flights made for the United States Army. The second method was to add another element to the fuel at high altitudes, as in some flights in France, for example, where wood alcohol was used.

The third method was that of direct supercharging, mainly by means of a centrifugal blower operated by a turbine driven by exhaust gases. In this connection some very fine work was done by Professor Rateau in France and Messrs. Sherbondy and Sanford A. Morse, Mem. Am. Soc. M. E., in this country. This method was devised by the British Napier and Sons Company, in their Lion machine. The engine of this machine was really designed to operate at densities far below atmospheric, so that if operated at atmospheric density at full throttle for any length of time it would probably fly to pieces. By a skillful proportioning of parts, however, the engine has been designed so that it can operate at ground level at part throttle, but develops its full rate of power at full throttle at an altitude of about 10,000 ft.

The solution of all of these problems represents what might be called a post-graduate course in gasoline engine design and it is predicted that we shall soon see material changes in the design of motorcar engines generally, brought about by the greater experience gained in the design of aeroplane engines.

Movement in Germany Toward Union of Technical Men

The following interesting translation of a German report was prepared by Sir Robert Hadfield, and shows the important steps being taken in Germany to bring about a Union of Technical Men, from foremen to technical chiefs. The report relates to the inaugural meeting of the Union held in Berlin, November 25, 1918.

Technical Men: Join! Forget what Separates You! Your Future Depends on It!

RAPID FORMATION OF LOCAL SECTIONS AN URGENT NECESSITY

The objects of the Union are as follows:

1 To ensure that Technologists may bring their influence to bear on Government, Parliament, and the Economic Life of the country.

2 To attain this object it will use every endeavour to bring the representatives of all branches of Technical Practice, from the Foreman to the Technical Chief, into one comprehensive organization.

3 The programme of the Union will be based on the foundations of a free, democratic Constitution.

4 The Union desires the active collaboration of its members in public life. In order to realize this programme, the Union will—

a *Inside Work:* Ensure its members a more clear comprehension of the conditions under which the people live, of national life, of legal machinery, administration, economy, politics, and cultural matters, with special reference to the systematic training of members capable of acting as the representatives of technology on public bodies.

b *Outside Work:* Explain to other circles of society the importance of technical work for the life of the people and the maintenance of civilization at the proper level of culture, and the necessity of leaving technical questions to be settled by technical men only.

5 The Union repudiates any unconstitutional attitude towards other circles of the population, and will use every endeavour to secure intelligent coöperation, based on trust and respect, with the working classes.

6 The Union declares it as necessary for securing its objects that its activities should provide means for an adequate existence for every one belonging to the technical trades or professions, in order that he may work independently of his own or outside support.

The first general meeting of the Union took place in the Rheingold, Berlin, on November 25, more than 2,000 technical men belonging to all branches and grades of the calling being present. On December 2 representatives met from all the larger technical societies of Greater Berlin, and agreed on the necessity for the formation of the Union and on the correctness of its aims. The majority of those present declared themselves ready to coöperate actively for the expansion of the Union.

The declaration containing this and other resolutions was signed, among others, by representatives of:

Committee of Technical Officials of the Ministry of Marine
Society of Architects
Automobile and Aeronautical Society
Society of German Engineers
Society of German Civil Engineers
German Technical Society
German Union of Technologists
Electro-Technical Society
Society of Naval Architects
Union of Academical Architects' Societies
Union of German Electrical Engineers
Society of German Patent Agents
Society of Surveyors
German Chemical Society
German Foundrymen's Society
Society of German Mechanical Engineers.

Negotiations with other bodies are under way and promise complete adherence to the objects.

NEWS OF THE ENGINEERING SOCIETIES

Reports of Meetings of Western Society of Engineers and American Steel Treaters' Society

Western Society of Engineers Discusses Transportation Situation

Remedies designed to bring about a readjustment of the transportation situation, particularly among electric railway lines, were presented by James Roland Bibbins, Mem.Am.Soc.M.E., associated with Bion J. Arnold, Chicago, and three other speakers, at the first regular fall meeting of the Western Society of Engineers, Chicago, on September 8.

The general subject of the evening's program, The Economic Future of Transportation Facilities, brought out a large crowd of public-spirited engineers. While the electric railway was used by all speakers as an illustration of a public utility, yet the discussion was so broad and far-reaching in its character that the plans as outlined might embrace a utility of any public nature, such as steam railroads, water works, lighting systems, etc.

The various alternatives named by Mr. Bibbins, and left to the body of engineers to determine whether or not they are equitable, were:

Capital may be sealed down, but by so doing we admit that the railway industry in its present form is a failure.

Operating deficits may be met by general taxation, but misplaces a burden on the man too poor to use the service.

The zone fare system would increase the number of short riders, but would tend to interfere with the freedom of inter-city transit.

Labor might accept a reasonable profit sharing plan.

Cities should assume a responsibility of providing special lighting, paving, etc., for the companies.

Cities might waive their share of the profits in order to reduce the price of fares or increase the service.

Lastly, the public might assume the risks of carrying a deficit through .. system of municipal ownership.

Mr. Bibbins, who is a recognized authority on transportation problems, declared that the five-cent fare is a psychological fact which has been bred into the minds of the people. Should the transportation companies revert to the old system of the five-cent fare and establish fare zones the population would become much more dense in the cheaper districts and tend to defeat the purpose of a cheaper fare—of getting the public away from the city into the suburbs. Only a study of the railway problem in its three phases, past, present and future, will bring about a happy medium of control. Public control of utilities should not be subjected to destructive radicalism or reaction, he declared.

The public, today, wants to pay only rates based on the depreciation value of utilities, Mr. Bibbins said, and it is for that reason that the continued hostility between the owners and the public has reached such a critical state. To offset the loss through depreciation, companies should have set aside at the time of beginning operations a depreciation reserve. The purchasing power of the five-cent fare has declined in comparison with the purchasing power of our currency and has decreased stability in the operating companies.

The speaker illustrated his discussion with a brief but thorough history of an electric railway company, operating in one of the large cities of this country, which electrified its roads in 1890 on an investment less than one-third of that of today. Because of ill-considerate competitive construction permitted by the city, extensions did not become normal until ten years later. During this period net earnings vanished. After 1900 the earnings of the company continued at a much lower rate until the beginning of the war. Today the earnings are negligible.

To establish electric railway companies on a paying basis for the future, one or more of the several alternatives outlined by Mr. Bibbins must be adopted only after an intelligent and comprehensive survey of existing conditions has been made. He urged that the engineering profession lend its ability and weight in rectifyng the mistakes that have been made in the past in handling technical problems of utility development.

Col. P. J. Kealey, president of the Kansas City Railway Company, who was unable to attend the meeting, sent a written discussion on valuation in which he declared that the ultimate solution of the present problems before the railway companies and the people will be private ownership and operation with municipal supervision of service. "The car rider should not be made pay for anything more than transportation," Colonel Kealey wrote. "In order to do this traction companies must be relieved of all indirect taxes." Public opinion is the only medium which can bring about a settlement of the labor problem for during the past two years seemingly promising settlements have been disrupted by the union.

The next regular meeting of the society will be held October 4 but section meetings are held every Monday evening throughout the month.

Harold T. Elliston,
Office of *Western Society of Engineers.*

Convention of Steel Treaters' Society

The National Convention of the American Steel Treaters' Society was held at the 7th Regiment Armory, Chicago, September 23rd to 27th.

The purpose of the convention was to promote the science and art connected with the heat treatment of steel and to bring into closer relationship, the members of the profession.

Eighty exhibitors placed for public inspection the latest developments of heat-treating appliances and products. The papers discussed cover every branch of the field. Notable among the speakers were Shipley N. Brayshaw, London; E. F. Collins, General Electric Company; W. G. Dauncey, associate editor, *Iron and Steel*, Montreal, Canada; Fred Grotts, Holt Manufacturing Co.; Wilfred Hanby, Rotherham, England; W. G. Lottes, International Harvester Co.; and Prof. A. E. White, University of Michigan.

The promoters of the exhibition were greatly elated over the success of the convention and predicted that a national convention, only on a much larger scale, would be held next year.

The American Steel Treaters' Society is a comparatively new organization but its influence is already being felt in the building up and advancement of the steel industry. Local chapters of the organization have been established in Chicago, Cleveland, Pittsburgh, Milwaukee, Philadelphia, Cincinnati, Buffalo, Rochester, and New York City. Others are to be organized in industrial centers.—H. T. L.

New England Water Works Association

The thirty-eighth annual convention of the New England Water Works Association was held at Albany, N. Y., September 30—October 3. In addition to a number of important committee reports, a number of interesting technical papers were presented. Norman J. Howard discussed the operation of a new drifting sand filter system at Toronto. The Schoharie development of New York City's water supply formed the subject of an address by J. Waldo Smith, Chief Engineer, Board of Water Supply. Another paper by Leonard Metcalf and William T. Barnes, of the firm of Metcalf & Eddy, consulting engineers, Boston, was devoted to the 10,000,000-gallon covered reservoir at Dayton, Ohio. Two papers on pumping engines were also presented: The first was by Creed W. Fulton of the Gould's Manufacturing Co., and the second by D. A. Decrow of the Worthington Pump & Machinery Corporation.

ENGINEERING COUNCIL

Engineering Council[1] is an Organization of National Technical Societies of America, Created to Consider Matters of Common Concern to Engineers, as Well as Those of Public Welfare in Which the Profession is Interested

Classification and Compensation of Engineers

In Mechanical Engineering for July (p. 632) there was presented the substance of a preliminary report of the Committee on Classification and Compensation of Engineers. Since that time there has also been made public a report prepared by the Canadian Civil Service Commission, which dealt with the same problem, and it is of interest, therefore, to compare this report with that prepared by the Council. The letter from the chairman of the Committee on Classification and Compensation of Engineers, accordingly follows:

New York, August 27, 1919.

Mr. Alfred D. Flinn, Secretary, Engineering Council,
29 West 39th St., New York.

Dear Sir:

From time to time within the past few weeks, you have forwarded to me various letters addressed to you concerning the proposed "Classification of the Civil Service of Canada" as recommended by Arthur Young & Company of Chicago, Toronto, and New York. The copy of this classification, which was also received, indicates that its preparation was authorized by the Canadian Parliament and that the work upon it was done under the direction of the Civil Service Commission.

Your correspondents offer objections to the classification, particularly on the ground that the compensations proposed for higher grades of service are inadequate. In view of the investigation now being made on behalf of Engineering Council as to the classification and compensation of engineers in Federal, State, Municipal, and Railroad service, this report is of more than usual interest, and especially so since Council's Committee is informed that Arthur Young & Company are performing a similar service for the Congressional Committee on Reclassification and Compensation of Government Employees, including engineers.

Engineering Council's Committee on Classification and Compensation for the State and Municipal services has tentatively proposed that all positions in these services be limited to 13 in number, of which 7 are distinctly professional, while the remaining 6 are in a class directly leading to professional work, but not necessarily of a professional character. In the questionnaire recently issued by the Committee the views of the responsible heads of the services affected are being sought, and in the responses which have been received up to the present writing, there has been practically unanimous agreement on the classification. The inquiry has not progressed far enough to warrant any expression as to the views concerning compensation other than to say that there is an unquestionably strong belief that if the engineering service is to be maintained on a proper plane, there must be a very substantial increase in pay.

The Canadian report appears to cover every position in the civil service. It is arranged alphabetically and in the absence of grouping, a complete analysis of the engineering service involves a task of a magnitude greater than I have found time for. I have attempted, however, to make such examination as time permitted and am impressed with a belief that the objections raised are well founded. No attempt seems to have been made to standardize titles. Consequently there are in the engineering service at least 157 independent titles as compared with the 13 titles proposed by our Committee. It is recognized that qualification of a general title to show the nature of the service rendered, is quite proper, but in the judgment of the writer there is no reason for treating similar positions as entirely unrelated and as warranting entirely independent specifications.

The report states that the compensations proposed are intended for "normal times" and that pending restoration of such times, the rates recommended should be "supplemented by a bonus," but no information appears as to the magnitude of the bonus.

From my study of the report it would appear that the groups and ranges of compensation, tabulated as far as practicable, under the classification tentatively proposed by Engineering Council's Committee are about as given in the accompanying table.

In general, promotion through most of the grades is by increments of about $120, the minimum and maximum rates of each being respectively higher and lower than the rates fixed for the grades below and above, thus resulting in a comparatively small salary range for each position and, in this respect corresponding with what seems to have been the general practice heretofore. This treatment is one which it would seem desirable to modify, to the end that the relative ability and experience of men performing similar work may be given adequate recognition.

Exceptions are noted in the case of "Topographical Engineer," where a salary range of from $2,160 to $3,120 is proposed, and in the case of promotion from "Junior Electrical Engineer" at a maximum salary of $1,980 to "Electrical Engineer" with a minimum salary of $2,640, each of the two latter grades having an extreme salary range of only $360. In the case of "Chief Draftsman," "Structural Engineer," and "Chief Topographical Engineer" maximum salaries are proposed of $3,000, $3,240, and $3,840, with no provision for promotion to other engineering grades, although for each position the qualifications required are such as to indicate ability to progress to high positions in the service. The table also shows that only 6 engineering positions are open to compensation at a rate of more than $6,000 per annum.

It would seem to the writer that this report is open to serious criticism on the grounds that it fails to group engineering service along orderly lines, that it provides too narrow limits for promotions within a grade, and that the compensation proposed for all grades, is inadequate for the service rendered. The latter criticism seems particularly pertinent in comparison with the rates now being demanded by organized labor. The practicability of properly meeting present day conditions by the addition of a "Special War Bonus" to the proposed rates in order to meet the present high cost of living is also to be questioned on the ground that, and as set forth in the circular letter issued by Council's Committee on Classification and Compensation of State and Municipal Engineers, the "revolutionary change in the cost of living" is one which "unless modified by further economic disturbance is likely to be permanent or to continue for a long time to come."

Very truly yours,
(Signed) Arthur S. Tuttle,
Chairman, Committee on Classification and Compensation of Engineers, and of State and Municipal Section.

TABULATION OF TITLES AND SALARIES FOR ENGINEERS IN CANADIAN CIVIL SERVICE REPORT UNDER CLASSIFICATION PROPOSED BY COMMITTEE OF ENGINEERING COUNCIL

Tentative Classification of Positions in State and Municipal Service Proposed by Engineering Council's Com. on State and Munic. Serv.	No. of Titles provided in proposed Canadian Classification.	Salary Range Proposed for Canadian Service				Qualifications proposed for Canadian Service
		Usual		Extreme		
		Min.	Max.	Min.	Max.	
Consulting Engineer	1	$6,000	......	......	......	Professional Engr. 12 years' experience (7 in ch'ge.)
Chief Engineer (major work)	5	6,000	......	$4,800	......	Professional Engr. 7-12 yrs.' exper. (3-7 in charge)
Chief Engineer (minor work)	7	3,900	$4,800	3,600	$6,000	Professional Engr 7-12 yrs.' exper. (3-7 in charge)
Chief Engineer—Deputy	8	3,900	4,800	3,600	5,700	Professional Engr 7-12 yrs.' exper (3-7 in charge)
Engineer	37	3,300	4,020	3,000	4,500	Professional Engr 5-10 yrs.' exper (2-5 in charge)
Senior Ass't Engineer	40	2,640	3,000	2,400	3,480	Professional Engr. 3 yrs.' exper. (2-3 in charge)
Assistant Engineer	23	2,100	2,580	2,040	3,120	Professional Engr. 3 yrs.' exper.
Junior Assistant	15	1,680	2,040	1,680	2,160	Professional Engr. 2 yrs.' exper.
Senior Draftsman	..		Included in Professional Service			
Draftsman	8	1,260	1,560	......	......	3 years' experiece
Junior Draftsman	4	900	1,200	......	......	2 years' experience
Chief Instrumentman	.		Included in Professional Service			
Instrumentman	5	1,260	1,560	......	......	3 years' experience
Rodman	4	900	1,200	...	...	2 years' experience

[1] Officers of Engineering Council: J. Parke Channing, *Chairman*, Alfred D. Flinn, *Secretary*; Engineering Societies Building, 29 West 39th Street, New York.

NATIONAL SERVICE COMMITTEE

Contributed by the Washington Office[1]

An Explanation of the Proposed Department of Public Works

The name Department of Public Works at once leads to a misconception of its scope. Public Works is a poor name but such a name, or its equivalent in other languages, has been almost universally adopted to embrace tangible property owned by a Government or that over which a Government has direct sovereign jurisdiction, together with all official functions and activities related thereto and necessary to public utility. There can be no fixed and comprehensive definition of public works, because that which may be considered a part of public works in one country may be altogether lacking in such qualifications in another.

It is, therefore, natural that the bill which proposes to establish a Department of Public Works in this country (see Mechanical Engineering for August, page 709, for the terms of the bill) should fail to propose public works jurisdiction over several Government properties or activities which, under strict construction of the definition, should be included. Conversely it includes Government bureaus, certain parts of which may not appropriately fall under a Public Works Department but which, at present, and pending reorganization, are so inextricably interwoven with purely public works functions that their separation is not now regarded as expedient. Because of this it appears desirable to explain many points of the bill which have puzzled those who are not in touch with the legislative and departmental situation in Washington. Such explanations therefore follow:

Why Is It Proposed to Transform the Department of the Interior Instead of Creating a New Department? First, because there are already enough Executive Departments to perform Government business, if the functions were properly corelated, and second, because there is a natural reluctance on the part of Congress to create new Departments. This latter reason, of course, would be an enormous handicap to any public works legislation.

Why Is It Proposed to Divide Control of the Duties of the Office of Indian Affairs? The main purpose of the Office of Indian Affairs is to educate the American Indian who is now a ward of the Nation, provide for his social welfare, and eventually create citizens. Therefore, the principal functions of this office fall under the branches of education and labor. When these objects are accomplished the Office of Indian Affairs will automatically go out of existence. The greatest and most important engineering work connected with this office, namely the construction of irrigation systems, is now and has for many years been performed by the Reclamation Service. Therefore, the proposal to divide the functions does little more than to continue a very advantageous arrangement already in effect.

Why Is It Proposed to Transfer from the War Department the Jurisdiction Over Rivers and Harbors? Because, entirely aside from the decidedly adverse opinions that the great body of engineers entertains as to the fitness of the Corps of Engineers, U. S. A., and its past performances, rivers and harbors improvements for navigation constitute a purely civil function which is merely one phase of our rivers and harbors development and utilization, and the whole cannot go forward effectively and economically without thorough coördination. Navigation improvements are public works, and are so defined the world over, and the fact that in an early day in the history of our Republic they were placed under the Corps of Engineers, as a purely emergency measure, which has since been continued by well directed influence and legislative inertia does not constitute the slightest reason why an illogical arrangement should be perpetuated.

Why Is It Proposed to Include the Construction Division of the Army in the Department of Public Works? Because this division is made up almost entirely of civilian engineers highly experienced in construction work who have, in connection with the war emergency, performed the most extensive and remarkable achievements in engineering construction ever performd by any one organization in the history of the country; because it has worked out a most effective plan of organization and operation which is in a large degree responsible for the results achieved and which could be amalgamated most efficiently with many of the peace-time construction operations of the Government; because the War Department has not provided for the perpetuation of this organization, as such, in its plan for a new military establishment, which is now the subject of investigation by Congress, and, at least by inference, proposes to allow the Construction Division to lapse or to merge its functions with certain old-line military departments where it will be in an environment entirely foreign to the spirit and practice which has caused it to be so unqualified a success; because the construction work which this Division has accomplished is for the most part, not military engineering at all, and the only military significance which it has is derived from the subsequent utilization thereof for military purposes; because when the United States entered the Great War it was necessary to organize the Construction Division under an extreme emergency attended by costly delay, and there should be an active construction organization in the service of the Government, which in the case of a future war could be made to function at an instant's notice as a construction branch of the military establishment. The only way by which this can be accomplished is to have such an organization in active practice in peace time work.

What Is the Reason for Including the Forest Service in the Department of Public Works? While it is true that the science of forestry, so far as its sylvicultural aspects are concerned, is an agricultural science the real problems of operation and maintenance of a National forest, as they occur under the conditions prevailing in this country, are more truly related to engineering than to agriculture. In the first place, forest reserves are unquestionably public works. They are properties owned by the Government and set apart for public purposes. The harvesting of lumber, fire prevention, the construction of roads and trails, the conservation of water, and the administration of water powers are unquestionably engineering operations. There is yet a third phase of the subject which is perhaps more important than the other two from the standpoint of efficient public administration. The bill retains within the proposed Department of Public Works certain bureaus of the Interior Department which have largely to do with public lands. These are the General Land Office, the Geological Survey, the National Park Service, the Reclamation Service, and the Bureau of Mines. These Services are concerned in a more or less intimate way with public land boundaries, surveys and the classification of the land for one or another purpose under the public land laws. It is of unquestionable advantage and productive of large economies to have these bureaus under one roof. The Forest Service, however, has quite as intensive relation to public land matters as has any of the other bureaus above mentioned—indeed, a far more intimate relation in many respects. Therefore, in view of the multiplicity of engineering functions necessarily comprised in the administration of forest reserves, together with the obvious public advantage of coördination in land administration, there seems to be no question but that distinct public advantage would result by including the Forest Service in the Department of Public Works, notwithstanding the fact that one of the important functions of such a service is pure forestry.

What Is the Explanation of the Section Providing for Four Assistant Secretaries? Much doubt has been expressed as to the ability of the Government to secure qualified men to accept these positions of Assistant Secretary at a compensation of $7,500 per annum. It is admitted that such compensation is inadequate but the figure was determined upon with full recognition of present legislative expediency. A compensation of $7,500 per annum is about 50 per cent greater than the present average salary of the Assistant Secretaries of Federal Departments. A saving factor is provided, however, in that these Assistant

[1] Washington Office in charge of M. O. Leighton, *Chairman*, National Service Committee, McLachlen Building, 10th and G Streets

Secretaries shall be included within the scope of civil service retirement laws. Such laws have been advocated for nearly a generation and the principle constantly gains strength. Undoubtedly some suitable law will be enacted in the near future. Properly qualified men will, in many cases, be content with moderate compensation during active life provided they are assured of suitable retirement pay after they have become superannuated. We are familiar with many notable examples in the Army and Navy. Every man who enters these two branches of the service faces a life of moderate income supplemented by retirement pay. This has attracted and will in the future attract good men who recognize that in practically every other walk of life there can be no certainty of income, either large or small.

Some good friends of this cause have questioned the plan concerning the assignment of duties to Assistant Secretaries according to the character of the work. They contend that if the work of any one Bureau should involve all the functions designated in the section, that is, engineering, architectural, surveys, and law, the said Bureau would have four commanding officers instead of one and confusion and loss of efficiency would result. This criticism is a result of misconception of the language. These Assistant Secretaries will not be chiefs of bureaus but merely arms of the Secretary of Public Works. The chief of any bureau will, as at present, have executive authority over all of the operations of his bureau. His ultimate superior will in all cases be the Secretary of the Department of Public Works. Were it possible to secure an omnipotent person as head of the Department, Assistant Secretaries would not be necessary, but as at present the world is not producing omnipotent men it is necessary to give a Secretary of Public Works the advantage of specialized brains. The four Assistant Secretaries proposed are in effect merely additional lobes of the Secretary's brain and are a part of his official entity. Instead of reporting to an individual as done under the present practice, the bureau chief will report to and take counsel of an expert.

The Engineer Corps Under the Proposed Army Reorganization

The so-called Army Reorganization Bill now before Congress provides for a largely increased Corps of Engineers. The total engineer personnel under the Regular Army organization now provided by law is 12,933, while the bill now before the Senate Committee on Military Affairs authorizes an enrollment of 28,338. The reorganization scheme provides that the Chief of Engineers shall have the rank of Major General, whereas under the present law he is a Brigadier General. Two Brigadier Generals are provided and the number of Colonels is increased from 23 to 43; Lieutenant Colonels from 30 to 52; Majors from 72 to 134; Captains from 152 to 322, and First Lieutenants from 148 to 431.

There is much speculation, inside as well as outside of the service, as to the source from which this largely increased personnel of engineer officers will be secured. It seems apparent that a large number of the newly created commissions must be filled through the Reserve Corps or otherwise. Unless some fundamental change is made in the method of selecting engineer officers from among West Point graduates a large proportion of the engineer officers in service will lack those exclusive qualifications, which have heretofore characterized the Corps, by reason of the fact that engineer officers are, under the present law, selected from West Point graduates who have attained the highest rank in academic studies.

It is reported that since the signing of the armistice about 1500 Regular Army officers have presented their resignations, and these include a number of engineer officers of the highest usefulness whose loss to the Corps will be severely felt. The Chief of Engineers in recent testimony before a committee of Congress commented upon the present low state of morale among Regular Army officers and it has been assumed that he included in this category the officers of his own department, as well as those in others. In any event the situation is interesting from the point of view of the civilian engineer because unless some expedient is adopted, the nature of which is at present not quite clear, it may occur that the enlarged engineering program of the War Department may make it possible for duly qualified civilian engineers to render service to the country via the military route, even in time of peace.

War Department Equipment for Trade, Technical Schools and Universities

A bill which was proposed in the last session of the 65th Congress,—"providing further educational facilities by authorizing the Secretary of War to sell at reduced rates certain machine tools not in use for Government purposes to trade, technical schools, universities and other recognized educational institutions,"—was re-introduced early in the present session of Congress and has just been reported favorably by the Military Affairs Committee.

An amendment has been affixed to this bill whereby the educational institutions are to pay 20 per cent of the purchase price of the tools even when depreciation is taken into consideration instead of 10 per cent as proposed in the original bill. In the meantime, the Director of Sales announces that the machine tool section is operating with representatives of the several bureaus of the War Department which have surplus machine tools and is fixing prices at which all standard tools held by the Department will be offered for sale. Because of the large and greatly diversified stock of these tools now held by the War Department, it is contemplated that the requirements of the technical schools can be amply and quickly taken care of following the passage of the proposed bill.

The Alaskan Railroad

When it became apparent that the Alaskan Engineering Commission would be unable to complete the Alaskan Railroad with the original appropriation of $35,000,000, a new bill was introduced into the House appropriating an additional $17,000,000 for this work. Up to September 15 the bill had passed the House and been favorably reported to the Senate calendar by the Committee on Territories.

The engineer of the Commission, J. L. McPherson, explained to the Committee why it was more economical to construct the line in two sections, and further explained that the original appropriation was insufficient because wages had increased 59 per cent, cost of material had increased up to 161 per cent, and cost of transportation up to 147 per cent. The average cost per mile of the completed line will not exceed $73,300, which is regarded by Mr. McPherson as a very good showing when the difficulties of railroad work in Alaska are considered. The road consists of 601 miles of track, including sidings.

The greatest expense yet to be met is for new work on various sections. One of the heavy items of expense will be the bridge over the Tanana river, which it is estimated will cost $1,220,298. Approximately $14,000,000 of the proposed appropriation is required for new work; the remainder is for reconstructing the Alaska Northern Railway, rehabilitating the Chatanika branch, constructing terminals and bridges, and for rolling stock and expenses in excess of revenue.

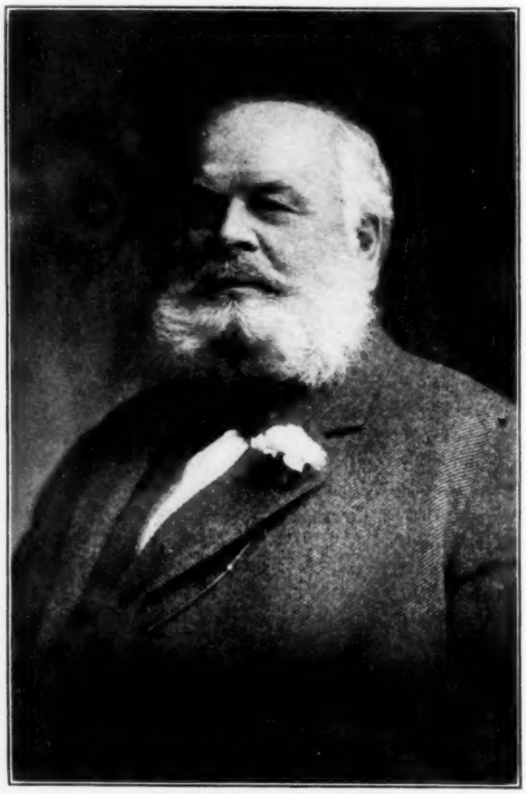
It is expected that the development made possible by this road will be comparable to the development which followed the construction of transcontinental lines in the United States. This is especially true if the main line of the road is connected with the base of Mt. McKinley.

Investigations of the Committee indicated that in addition to the mineral resources of Alaska which this road will open up, there is every prospect of Alaska becoming an important producer of agricultural crops. Investigation further developed that private capital had probably not built a line through this country because the government owns 99 per cent of the area of Alaska, which makes the government the logical interest to construct such a railway.

NECROLOGY

EDWARD PAYSON BATES

Edward Payson Bates, a life member of the Society, died on August 3, 1919, in Butte Mont. Mr. Bates was born on March 3, 1844 in Savannah, Ga. His parents were of New England stock; his father, Levi Whitcomb Bates, was a descendant of Clement Bates, who came to this country from England with his brother Joseph. They, in turn, were descendents of John Bate (or Bates) of Lydd, England, who was a mayor of the town and justice in the court. His mother was Ruth Ann Bailey. She was born in Meredith, Delaware County, N. Y. Her father, Timothy Bailey, was a skillful mechanic and inventor, having invented the knitting frame which made underclothes and made radical changes in the spinning jenny which tended to save time and decrease the cost of producing cloth. This knitting frame was first used in Cohoes, N. Y. and is in use there to this day.



Edward Payson Bates

Mr. Bates was a born mechanic, his ideas running in that direction from the time he could handle a hammer and saw, which was very early in his experience. At the age of seventeen he entered the machine shop of Hobart B. Bigelow, in New Haven, who was afterward one of the beloved governors of the State of Connecticut. He remained there only a short time when he moved to New York State in the vicinity of Albany and entered a machine shop. After two years he could do all the ordinary work skillfully and correctly. He received a journeymen's wages for the second year of his experience, during that time learning to assemble a locomotive and operate it on the road. His next move was to New York City where he learned how to build a marine engine and install it in a ship. He studied at nights with a professor connected with Cooper Institute, was granted his marine license and for several years went to sea as an engineer.

During the Civil War he saw service on a transport which was bearing home the wounded from Libby Prison. Soon after this, Willis Warner, widely known in engineering circles, his childhood friend, induced him to enter his employ to learn how to erect steam-heating apparatus, with the idea of opening a branch business in Syracuse, N. Y. That business he was thereafter engaged in, the character changing much from time to time. He added to it ventilation, hot-water heating, factory equipment, power plants, sprinkler work, and various contracts of a similar nature. He was in Mr. Warren's employ for several years when the latter's sudden and unexpected death threw him on his own resources. He was enabled by fortuitous circumstances to buy out the business and it was known thereafter as Bates & Johnson Co. Upon taking over the business he increased the number of branches until at one time there were offices of the concern in eleven cities. As conditions changed and trade unions made drastic rules he found it advisable to cut off business conducted at a distance and limit himself to two offices—the principal one at Syracuse and a branch at Utica. At the beginning of 1917 Mr. Bates incorporated the business under the laws of New York State and was the new company's first president, Mrs. Bates being one of the directors. The company proposed to carry on the same line of business which Mr. Bates, himself, organized and maintained.

Mr. Bates was a member of the Society of Naval Architects and Marine Engineers, charter and life member of the Technology Club of Syracuse, life member of the Mayflower Society of Massachusetts, life director of the American Bible Society, life member of the Archæological Institute of America, member of the Robert Fulton Memorial Association, life member of the Bates Association and director of the Syracuse Museum of Fine Arts. In 1910, Mr. Bates was appointed official delegate of the Society of Naval Architects and Marine Engineers to the Fiftieth Anniversary of the foundation of the Institution of Naval Architects, which was held in London.

In the middle of March, 1919, Mr. and Mrs. Bates started on an extended trip that took them southward to New Orleans by steamer, through Texas into Southern California, north to Alaska, then through Yellowstone Park; a singularly happy and delightful trip which was interrupted in Butte, Mont., by his peaceful death.

CHARLES H. McGWIRE

Charles H. McGwire, assistant chief engineer for the Board of Public Utilities, Los Angeles, Cal., died on August 6, 1919. Mr. McGwire was born in 1868 in High Ridge, Conn. He studied for one year in Cornell University. He was formerly connected for varying periods with the following firms: Daniels & Fisher Store Co., Denver, Colo.; Barber Asphalt Paving Co., Denver; Frazer Mountain Copper Co., Twining, N. M.; Longmont Sugar Co., Longmont, Cal.; Pacific Electric Railroad Co., Los Angeles, and the Busch-Sulzer Bros. Diesel-Engine Co., Los Angeles. Mr. McGwire became a member of the Society in 1909.

CARL ANTHONY HEILMANN

Carl Anthony Heilmann, Captain, 5th Engineers, U. S. A., died July 12, 1919, as a result of an accident near Camp Humphreys, Alexandria, Va., when an army motor truck plunged over the side of a bridge.

Carl Anthony Heilmann

Captain Heilmann was born in Brooklyn, N. Y., January, 1886. He was a graduate of Manual Training High School, and also studied at Worcester Polytechnic Institute for two years, graduating in 1908 as a mechanical engineer from Purdue University, where he completed the studies begun in Worcester. He served his apprenticeship in various machine shops during summer vacations. He was associated with the Ideal Portland Cement Company, Portland, Colo., as draftsman; with the Monett Electric Light Company, Monett, Mo., where he had charge of the electrical equipment and construction; with the Green Fuel Economizer Company in the capacity of sales engineer; with the American Radiator Company as engineering representative, Philadelphia, Pa.; and with Warren Webst r and Company, as district manager, Washington, D. C.

Captain Heilmann had been stationed at Camp Humphreys after eight months of arduous service in France, with the First Division, having returned to the United States in order to make a lecture tour of the country. He entered the service shortly after the declaration of war and was commissioned as first lieutenant, Engineer Corps, at Fort Myer, Va., in June, 1917. He was promoted to Captain soon after his return to the United States. Captain Heilmann was elected to membership in the Society in 1913.

THEODORE COOPER

Theodore Cooper, for 30 years one of New York's best known consulting engineers, and an authority on bridge design and construction, died August 24 at his home in New York City. Mr. Cooper was born at Cooper Plains, N. Y., January 12, 1839. He was an engineering officer in the Navy during the Civil War, and assistant professor at the Naval Academy from 1865 to 1868. He was one of the five expert engineers selected by the President to determine the Hudson River bridge span and a member of the board of experts on the Manhattan Bridge plan in 1903. He had also been consulting engineer for the New York Public Library and the Quebec Bridge. He retired ten years ago.

PERSONALS

In these columns are inserted items concerning members of the Society and their professional activities. Members are always interested in the doings of their fellow-members, and the Society welcomes notes from members and concerning members for insertion in this section. All communications of personal notes should be addressed to the Secretary, and items should be received by October 15 in order to appear in the November issue.

CHANGES OF POSITION

Robert P. McCarty has become associated with the Electric Boat Company, Groton, Conn. He was formerly connected with the Knox Motors Company, Springfield, Mass.

J. Harland Billings has resigned his lectureship in machine design in the University of Toronto, to become professor of mechanical engineering at Drexel Institute, Philadelphia, Pa.

Arthur S. Lewis, formerly with Flint and Chester, Inc., New York, as assistant to the president, has become affiliated with the Barco Manufacturing Company, Chicago, Ill.

George N. Somerville, until recently, chief engineer, Skandia Pacific Oil Engine Company, Oakland, Cal., has joined the staff of the Pacific Marine Review, San Francisco, Cal.

Carleton A. Orr has become associated with the Baker Steam Motor Car and Manufacturing Company, Inc., Pueblo, Colo. He was formerly connected with the Arkansas Valley Railway, Light and Power Company, Pueblo, Colo., in the capacity of superintendent of power plant and shops.

C. H. Vickers, formerly with the Willys-Morrow Company, Elmira, N. Y., has accepted the position of machine designer with the Utah Copper Company, Garfield, Utah.

Robert B. Stanton, Jr., has entered the service of the United Cast Iron Pipe and Foundry Company, New York. He was, until recently, sales engineer with the Worthington Pump and Machinery Company, New York.

Paul A. Cushman, formerly assistant professor of mechanical engineering, Pennsylvania State College, State College, Pa., has become affiliated with the mechanical engineering department, The Polytechnic Institute, Brooklyn, N. Y.

Noyes D. Farmer has become associated with the Carborundum Company, Niagara Falls, N. Y. He was formerly connected with the Atlantic Corporation, Portsmouth, N. H., in the capacity of supervisor of costs.

C. C. Wilcox has assumed the duties of chief engineer of the Durant Building Corporation, Detroit, Mich. He was recently assistant to consulting electrical engineer, Hodenpyle, Hardy and Company, Jackson, Mich.

Millard F. Cox has assumed the duties of first vice-president and consulting engineer, Louisville Fire Brick Works, Highland Park, Ky. He was formerly connected with the Louisville and Nashville Railroad Company, Louisville, Ky., in the capacity of assistant superintendent of machinery.

Eric L. Bergland has entered the employ of Brokaw-Eden Company, New York. He was, until recently, engineer with the E. I. duPont de Nemours and Company, Wilmington, Del.

Antell A. Lloyd, formerly maintenance draftsman, Hillsboro Mills, Wilton, N. H., has accepted the position of designer, Springfield Armory, Springfield, Mass.

Walter C. Setzer, formerly instructor, mechanical engineering department, University of Pennsylvania, Philadelphia, Pa., has accepted the position of mechanical engineer for The H. B. Smith Company, of the same city.

Clarence W. Lewis, until recently with the Empire Gas and Fuel Company, Eldorado, Kan., has entered the service of the National Petroleum Corporation, New Orleans, La., in the capacity of district engineer.

James T. Enes has become associated with Perin and Marshall, of New York. He was formerly designer, Garfield Works of the Tennessee Coal, Iron and Railroad Company, Birmingham, Ala.

Harry S. Badger has accepted the position of resident engineer, American Cities Company, Houston, Tex. He was formerly connected with Vanderbilt University, Nashville, Tenn., in the capacity of engineer.

J. E. Fricker, formerly superintendent, liquid air division, Air Nitrates Corporation, New York, and more recently with the American Cyanamid Company, Niagara Falls, Ont., in a consulting capacity, has assumed the duties of superintendent with the Niebling-Markstein Company, of Cincinnati, Ohio.

Henry R. Trotter has assumed the duties of president of the Trotter-Patterson Corporation, consulting engineers, Hartford, Conn. He was formerly connected with the S K F Industries, Inc., in the capacity of chief engineer.

Leon K. Davis, until recently fire protection engineer, U. S. Railroad Administration, Washington, D. C., has become affiliated with the New York Reciprocal Underwriters, N. Y.

Charles T. Owens has accepted the position of one of the assistant chief inspectors with the U. S. Shipping Board, New York. He was formerly in the employ of the Alabama Power Company, Birmingham, Ala.

Morris Wenk, formerly engineering draftsman, G. M. Standifer Construction Corporation, Vancouver, Wash., has assumed the position of instructor in mechanical drawing at Oregon Agricultural College, Corvallis, Ore.

Byron F. Stowell, for many years connected with the Hendee Manufacturing Company, Springfield, Mass., as master mechanic and mechanical engineer, is now associated with the Napier Saw Works, Inc., of Springfield, Mass., as mechanical engineer.

Fred J. Queripel, formerly with the Electric Furnace Construction Company, Philadelphia, Pa., as chief draftsman, is now doing plant engineering work for the National Aniline and Chemical Company, Marcus Hook, Pa.

S. J. Millard, until recently instructor in industrial engineering, Pennsylvania State College, State College, Pa., has become associated with the Scranton Technical High School, Scranton, Pa.

B. F. Safberg, formerly with the production department of the Emergency Fleet Corporation, Plainfield, N. J., is now a member of the Technical Advisory Committee of the War Claims Board, Washington, D. C.

V. Edgar Walters has severed his connection with the Savage Arms Corporation, Utica, N. Y., to accept a position with the General Motors Corporation, Detroit, Mich.

Howard E. Degler has accepted the position of mechanical engineer with the McClintic-Marshall Construction Company, Pottstown, Pa. He was formerly instructor in automobile technique, United States Training Detachment, Hampton Institute, Hampton, Va.

Harry C. Buffington, formerly motor engineer, Minneapolis Steel and Machinery Company, Minneapolis, Minn., has assumed the position of chief engineer, The Holt Manufacturing Company, Peoria, Ill.

William H. Baker has resigned from the Atlas Portland Cement Company and has joined the staff of the Hardinge Conical Mill Company, New York, as vice-president.

Robert W. Rogers, until recently employed by the United States Government as a training expert in the Department of Labor Training Service, is now directing the Shop Training Department which has recently been established by the Wilson Foundry and Machine Company, Pontiac, Mich.

Irving E. Tuttle, formerly with Meyer, Strong and Jones, consulting engineers, has become president of the Nate-Earle Company, New York, engineering contractors in power plants, heating and ventilating systems and piping of all descriptions.

L. H. Schickedanz, until recently assistant mechanical engineer with the Cleveland Cliffs Iron Company, Ishpeming, Mich., has become connected with the United States Fuel Company, Westville, Ill.

Harold B. Bernard has been relieved as assistant superintendent, Sinclair Cudahy Pipe Line Company, Tulsa, Okla., to become general superintendent of the gasoline department of the Sinclair Companies, Tulsa, Okla.

Walter K. Cabot has accepted a position with the American Can Company, New York. He was formerly assistant manager with William Underwood Company, Boston, Mass.

Robert S. Drummond has become affiliated with the American Pressweld Radiator Corporation, Detroit, Mich. He was until recently general manager of the Wilson Welder and Metals Company, Inc., New York.

F. W. Leahy has resigned from the Emergency Fleet Corporation to assume charge of the marine department of the Diamond Power Specialty Company, Detroit, Mich.

F. J. Schlink, associate physicist, Bureau of Standards, and for the past two years technical assistant to the director of the Bureau, has resigned to accept a position as physicist with the Firestone Tire and Rubber Company, of Akron, Ohio.

Burt A. Waltz has severed his connection with the B. F. Goodrich Company, of Akron, Ohio, and has become associated with the Osborn Engineering Company, consulting engineers of Cleveland, in the capacity of assistant mechanical engineer.

J. H. Sengstaken, formerly associated with Lewis A. Riley, of New York, as engineer, has assumed the duties of assistant works superintendent of The Green Fuel Economizer Company, Beacon, N. Y.

Louis J. Pelissier, formerly mechanical superintendent at the works of the Marlin Rockwell Corporation, Tacony division, has become connected with the Edison Lamp Works of the General Electric Company, Harrison, N. J., in the capacity of foreman in the experiment and development department.

Alvin L. Smith has accepted the position of engineer with the Coldwell Lawn Mower Company, of Newburgh, N. Y. He was, until recently, plant engineer with The Griest Manufacturing Company, New Haven, Conn.

ANNOUNCEMENTS

I. E. Moultrop has been elected chairman of the Technical and Hydro-Electric Section of the National Electric Light Association.

W. S. Hazzard has become affiliated with Adams, Evans and Company, New York.

Alfred S. Kellogg has consolidated his engineering office with that of the architects, Brainerd, Leeds, of Boston. The new firm, under the name of Brainerd, Leeds and Kellogg will devote its entire energies to the design of complete structures, including architecture and engineering.

E. Everett Buchanan, Jr., has accepted the position of assistant in the metallurgical department of the Willys-Morrow Company, Elmira, N. J.

S. R. Willock has entered the employ of The Woodard Machine Company, Wooster, Ohio.

Lieut. Fred E. Hosmer, Aviation Section, Ebbetts Field, Tonoke, Ark., has become affiliated with the Gulf Production Company in the capacity of chief engineer.

The production division of the American Car and Foundry Company will be directed by William C. Dickerman who will be designated as vice-president in charge of operations. Mr. Dickerman has been connected with the company since its incorporation in 1899 advancing from apprenticeship in the shop to his present position.

Franklin R. Magill, Sergeant Q. M. C., N. A., Motor School, Camp Holabird, Baltimore, Md., has become identified with the Poole Engineering and Machine Company, New York.

C. B. Veal has become associated with the Curtiss Aeroplane and Motor Corporation, New York.

W. D. Hoxie, formerly vice-president of the Babcock and Wilcox Company, New York, has been elected president of the company.

Henry L. Wilson, Lieutenant, Q. M. C., A. E. F., has accepted the position of mechanical engineer with the Atlantic Dyestuff Company, of Boston, Mass.

K. Jellum, 2d Lieut., 308th Engineers, has become connected with the Western Electric Company, Chicago, Ill., as designer of special machinery.

Henry S. Johnson has become associated with the engineering department of E. I. duPont de Nemours Company, Wilmington, Del.

Robert P. Messenger, for the past nine years connected with the International Harvester Company, has now been promoted to the position of inspector general of European experiments of the same company, with headquarters in Brussels, Belgium.

A. L. DeLeeuw, formerly associated with the Singer Manufacturing Company, Elizabethport, N. J., has opened a consulting engineering office, at 149 Broadway, New York, for the building and equipping of industrial plants, specializing in machine shop problems to economic production.

Joseph S. String, Major Ordnance, U. S. A., has received his discharge from the Army and has become associated with Charles A. Lunn under the firm name of String-Lunn Company, engineers and contractors, industrial and power-plant equipment, with headquarters in New Haven, Conn.

Lee E. Barrows, formerly with the Texas Company, Fort Worth, Tex., has assumed the position of superintendent, gasoline division, producing department of the Houston, Tex., office of the company.

Levin A. Moore has assumed the duties of treasurer and general manager of H. W. Schrimpf and Company, Perth Amboy, N. J.

Howard M. Ingham has resumed his professional practice as industrial engineer after 18 months of service in the U. S. Naval Reserve Force, in the capacity of assistant naval inspector of ordnance, in charge of inspection in several plants engaged in the manufacture of ordnance, and is again prepared to take up problems in all phases of industrial engineering. He has associated himself with the firm of C. D. Giles and Company, accountants and auditors, New York.

John E. Taylor, Private, Company F, 31st Engineers, A. E. F., has accepted a position with the Locomotive Superheater Company, New York.

William H. Gref, Captain Ordnance Department, Frankfort Arsenal, Philadelphia, Pa., has become associated with the T. B. Foster and Brother Company, of Providence, R. I.

O. N. Edgar has left the Chamber of Commerce, Houston, Tex., where he had been in the capacity of engineer in charge of the industrial department, and has opened an office for industrial engineering work in a consulting capacity.

Leland G. Knapp, formerly affiliated with the Wisconsin Motor Manufacturing Company, Milwaukee, Wis., has become a member of the firm of Goodwin and Knapp industrial engineers, of Chicago, Ill.

George B. Massey, who was engaged in mine-laying work in the North Sea during the war, has left the United States Navy and has resumed his work as consulting engineer on excavation, with offices in Chicago, Ill.

George W. Mixter, vice-president of Deere and Company, Moline, Ill., has been named vice-president and general manager of the Pierce-Arrow Motor Car Company, Buffalo, N. Y. Mr. Mixter will retain his business relations with Deere and Company.

Ulysses G. Rogers, formerly in charge of the plant of the Smurr and Kamen Machine Company, of Chicago, Ill., manufacturers of turret lathes and special wire-working machinery, resigned his position August 1, and with W. W. Franklin and C. E. Schryver has organized the Commercial Engineering Association, Chicago, Ill., designers and builders of machinery, tools and equipment for the wire-working industry.

Francis L. Hill, Captain, 55th Infantry, A. E. F., is now assistant in graphics and descriptive geometry, Virginia Polytechnic Institute, Blacksburg, Va.

James F. Cyphers, Captain, Ordnance Department, U. S. A., Picatinny Arsenal, Dover, N. J., has entered the engineering department of E. I. duPont de Nemours and Company, Wilmington, Del.

W. T. Ayer has entered the employ of the Hercules Powder Company, Wilmington, Del.

James M. Forsyth, First Lieutenant, U. S. A., Air Service, is a member of the firm of Forsyth Engineering Company, Temple, Tex., which was organized by soldiers who were assigned to duty at the Aviation Repair Depot at Dallas, Tex., for the purpose of operating a first class machine shop.

APPOINTMENTS

William H. Timbie, until recently head of the Department of Applied Science, Wentworth Institute, Boston, Mass., has been appointed associate professor of electrical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

Sverre Petersen has been appointed head of the technical department of the Roxana Petroleum Company of Oklahoma, St. Louis, Mo.

Paul J. Kiefer, formerly with the Towne Scientific School, University of Pennsylvania, and recently released from active service as Lieutenant, U. S. Naval Reserve Force, has been appointed assistant professor of steam engineering, University of Illinois, Urbana, Ill.

Joseph W. Roe, formerly assistant professor, mechanical engineering, Sheffield Scientific School, Yale University, New Haven, Conn., has been appointed secretary to Dr. W. F. M. Goss, Past-President, Am. Soc. M. E., president of the Railway Car Manufacturers Association, New York.

LIBRARY NOTES AND BOOK REVIEWS

BOILER FEED WATER. A Concise Handbook of Water for Boiler-Feeding Purposes (Its Effects, Treatment and Analysis). By Percy G. Jackson. J. B. Lippincott Co., Philadelphia, 1919. Cloth, 5 x 7 in., 102 pp., $2.

Contents: Mineral Constituents; Corrosion; Softening; Selection of Softening Plates; Priming; Scale, Grease and Overheating; Methods of Analysis; Analysis of Scale; Control Tests for Water Softening; Sampling; Solutions. Appendix: List of Factors; List of Atomic Weights; Clark's Table of Hardnesses.

This volume is intended to be a reliable, concise and practical compendium of information on boiler waters and feed-water troubles. It is based on long experience as chemist to an English boiler insurance company.

ELECTRIC POWER TRANSMISSION. Principles and Calculations, including a Revision of "Overhead Electric Power Transmission." By Alfred Still. Second Edition. McGraw-Hill Book Co., Inc., New York. 1919. Cloth, 6 x 9 in., 407 pp., illus., tables, $3.50.

"Overhead Electric Power Transmission" was written to provide a discussion of the fundamental principles and scientific laws determining the correct design of overhead transmission lines, suited to the needs of the office engineer in charge of calculations and specifications. The addition of a chapter on underground conductors has now made it necessary to alter the title. The work has also been thoroughly revised, obsolete matter has been omitted and new material added.

MANUAL OF THE CHEMICAL ANALYSIS OF ROCKS. By Henry S. Washington. Third edition. John Wiley & Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 283 pp., 1 pl., tables, $2.50.

The author's object is to present a selection of methods for the analysis of silicate rocks, especially those of igneous origin, adapted to the needs of chemists, mining engineers, etc., who have not made a particular study of quantitative analysis. The present edition has been thoroughly revised and considerably enlarged.

MECHANICAL DRAWING FOR HIGH SCHOOLS. A Text with Problem Layouts. By Thomas E. French and Carl F. Svensen. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 221 pp., illus., tables, $1.25.

The object of this book is to present mechanical drawing as a definite educational subject by which the student's power of visualization may be developed and his constructive imagination strengthened, while he is also taught to think exactly, to understand and make mechanical drawings and to know modern drafting-room practice. The course outlined covers two years' work and is a complete textbook and book of problems.

THE NAVAL ARCHITECT'S, SHIPBUILDER'S AND MARINE ENGINEER'S POCKETBOOK. By Clement Mackrow and Lloyd Woollard. Twelfth edition. The Norman W. Henley Publishing Co., New York, 1918. Flexible cloth, 4 x 7 in., 760 pp., illus., tables, $6.

The twelfth edition of this pocket-book appeared two and one-half years after the eleventh, from which it differs by the correction of errors and the addition of seventeen pages containing supplementing notes on various sections of the book and an article on estimating the weight and cost of a merchant vessel. In addition to the subjects usually discussed in such works, articles on aerodynamics and aeronautics are included.

PRACTICAL HELPS for the Electric Railway Shop, Track, Power, Line and Rolling Stock Departments. Compiled from the Mechanical and Engineering edition of *Electric Railway Journal*. First edition. Published by *Electric Railway Journal*. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 331 pp., illus., tables, $2.

Contents: Track and Structures, by R. C. Cram; Power Generation, by Hartley Leh Smith; Power Transmission, by Charles R. Harte; Car Design, by Norman Litchfield; Car Equipment, by C. W. Squier.

These extended articles have been selected from a series published in the *Electric Railway Journal*, which was prepared for the information of men responsible for the upkeep of the physical equipment of an electric railway system. These articles cover the fundamentals of the various subjects in a broad practical manner.

PUMPING MACHINERY. A Treatise on the History, Design, Construction and Operation of Various Forms of Pumps. By Arthur M. Greene, Jr. Second edition, revised. John Wiley & Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 703 pp., 504 illus., tables, $4.

Gives a brief, historical review of the development of pumping machinery, describes the action of a number of common forms of pumps and states the methods of design of pumping apparatus. It is intended to develop certain general principles of mechanics which are applicable to pumping machinery as well as to train the student in application of the theoretical portions of an engineering course. The descriptive chapters on modern pumps have been prepared from the catalogs and bulletins of manufacturers and from current technical literature. A full bibliography is included.

SHORE PROCESSES AND SHORELINE DEVELOPENT. By Douglas Wilson Johnson. First edition. John Wiley & Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 601 pp., 149 illus., 73 pl., $5.

Professor Johnson has recorded in compact form the results of an extended study of the scattered literature on shore processes and shoreline forms. Water waves, the work of waves, current action, the development of the shore profile and the shoreline, shore ridges and minor shore forms are discussed, and a statement of the fundamental principles which seem best established is given. The author hopes that the book will prove useful to engineers, geologists, and geographers. Full lists of references and a bibliography are included.

STANDARDIZATION OF MINING METHODS. By Charles A. Mitke. A series of important articles reprinted from *Engineering and Mining Journal*. First edition. Published by *Engineering and Mining Journal*. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 5 x 7 in., 110 pp., 47 illus., 6 charts, 4 tables, $1.50.

As mining engineer for the Phelps Dodge Corporation the author has studied mining practices in detail, with a view to the establishment of standard methods. The present volume is based on his experience and is an account of the standardization of various mining practices in the interests of safety and economy.

STUDIES IN THE CONSTRUCTION OF DAMS: EARTHEN AND MASONRY. Arranged on the Principle of Question and Answer for Engineering Students and Others. By Prof. E. R. Matthews. J. B. Lippincott Co., Philadelphia, 1919. Paper, 6 x 9 in., 43 pp., 30 illus., $1.50.

This book is intended for students preparing for examinations, especially those for associate membership in the Institution of Civil Engineers, or the Institution of Municipal and County Engineers, or for the degree of bachelor of science in engineering in universities.

A TEXT-BOOK OF HEAT ENGINES. By Andrew Jamieson. Vol. 1; eighteenth edition. Revised by Ewart S. Andrews. J. B. Lippincott Co., Philadelphia, 1919. Cloth, 5 x 8 in., 551 pp., $3.

This volume is a revised edition of Professor Jamieson's "Textbook on Steam and Steam Engines," with the omission of the chapters on steam turbines and boilers. The omitted chapters, with others on thermodynamics, entropy and internal combustion engines will appear in volume two.

CENTRIFUGAL COMPRESSORS

(Continued from page 799)

(c) DETERMINATION OF THE BASIC CHARACTERISTIC FROM A GIVEN PRESSURE CHARACTERISTIC

From magnitudes obtained by measurement can be determined the average temperature T_1 at the entrance to the groups, the average temperature of the cooling water T_k and the average ratio of temperatures $\frac{T_2}{T_1}$. The average ratio of pressures of the groups is again

$$\frac{p_2}{p_1} = \left(\frac{p_{II}}{p_I}\right)^{\frac{1}{i}}$$

Further, the total work of compression E_g has to be measured. If, for a certain speed of rotation in revolutions n_0 a certain load be taken as normal there follows from equation [17] the average admission ϵ_m of the groups corresponding to any weight of the air flowing through the compressor G. Equation [4-b] permits determining the value of $\left(\frac{m}{\eta}\right)_m$. From this, by using Equation [16] and an estimated value of T_m (which is closer to T_2 than T_1), the magnitude of the pressure head m may be determined and from this may be determined the coefficient of efficiency η_m by using the expression $\left(\frac{m}{\eta}\right)_m$. This gives the corresponding points of the basic characteristic and all that remains to be done is to determine the coefficient of heat transmission k_0 and the exponent q. The best way to do this is to insert into Equation [1] various arbitrary values of a until the value of the ratio of temperatures $\frac{T_2}{T_1}$ is secured, which agrees with the average value obtained by direct measurement. If this be properly done equation [13] ought to be satisfied also (this gives a test of the correctness of the value of T_m. Thereafter from Equation [14] may be computed the value of

$$z = k_0\left(\frac{G}{G_0}\right)^{1-q}$$

If this determination be carried out for several points of a given characteristic and if in accordance with Fig. 5

$$\log Z = \log k_0 + (1-q)\log\frac{G}{G_0} \qquad\text{[18]}$$

be plotted as a function of $\log \frac{G_0}{G}$, the straight line AB may be drawn through these points, and then

$$OC = \log k_0$$

$$\frac{OC}{OA} = 1 - q$$

This determines the value of k_0 and q.

As has been shown in a previous investigation of the author concerning a new process for the calculation of centrifugal compressors Equation [11] holds good under the assumption that the coefficient of heat transmission is the same throughout the entire group of stages. This is, however, actually not so, and in order to take this factor into consideration it is necessary in accordance with Fig. 5 to set the end temperatures $T_2 - T_{02}$ as well as T and T_q in Equations [11], [15] and [17] somewhat higher than corresponds to their actual values.

GAGE LIMITS IN INTERCHANGEABLE MANUFACTURING

(Continued from page 805)

If both mating parts of the work have errors in lead in the same direction, the work will go together easier, because these errors in lead in the work require enlarging the threaded hole and reducing the screw to receive the gages their whole length, and when these mating parts come together, the errors being in the same direction, the flanks of the threads coincide, and the above-mentioned compensation in diameter for lead error makes the mating parts loose. This condidition is often blamed on the gages, when, as a matter of fact, the error in lead on the work reduces the tolerance in order to allow the work to mate, and the gage only insures the mating.

As master gages cannot be made exactly to the component dimensions, except at a prohibitive cost, the inaccuracy comes out of the working tolerance for the reasons before stated, and on close work this should be taken into account when setting the component tolerance. If the minimum screw plug gage has an error in angle, it necessitates that the nut be made larger in pitch diameter than that of the gage in order to be accepted, therefore errors in angle on the minimum plug gage reduce the working tolerance.

If the maximum screw plug gage has an error in angle, it facilitates the approval of the work or adds to the working tolerance, as will be plainly seen if a maximum gage with thread angle 50 deg. be used to check a nut whose thread angle is 60 deg. The pitch diameters being alike, the plug would "no-go" into the threaded hole, thereby passing the work which is off on the angle. Therefore, these gage angle errors off-set each other, and do not rob the tolerence. From what has been said before, it is plain that errors of lead in the "go" screw thread gage rob the tolerance slightly, and this should be taken into account on close fitting work.

The "no-go" thread gage is not expected to go more than a couple of threads, hence the lead error in the "no-go" gage can be neglected. The total errors then which can affect the final working tolerance, if all are in the same direction, are two diametrical errors, and the diametrical equivalent of the lead error of the "go" gage.

Some engineers think that the law of averages ought to apply in this condition by assuming that on an average only half of the errors ought to be present in one set of gages, and that the allowance on the tolerances as affected by master gages should be one half of the sum of the three above-mentioned errors.

The new Webster's Collegiate Dictionary and Webster's New International Dictionary fail to give any shade of difference in meaning between the use of the words "electrical" and "electric," and yet those of us who constantly mingle with men of the electrical engineering profession know there is a decided difference in usage.

For instance we hear constantly of an "electrical" engineer, never an "electric" engineer, and almost universally we hear of "electric" toasters, and quite infrequently do we hear of "electrical" toasters. By study of such instances as these we are able to formulate a rule that will guide us in the most elegant or choice use of these words.

It would seem that the use of the word "electric" is preferred where a piece of machinery or apparatus is involved that is worked or operated by electricity and in almost all cases where inanimate things are to be modified. Thus we have "electric" current, "electric" baker (meaning a stove operated by electricity), "electric" trolley, "electric" supply company (a store that deals in "electric" supplies).

On the other hand, when matters pertaining to things or people connected with "electrical" affairs but not necessarily involving the direct use of electricity are considered, especially where people and organizations are described, the word "electrical" is preferred in its use. Thus we have "electrical" baker (one who operates an "electric" baking apparatus), "electrical" engineer, "electrical" supply jobbers' association, "electrical" contractors and dealers' association, "electrical" engineering profession, and among inanimate uses, "electrical" science, "electrical" affairs and such other instances as may be cited where electricity is not directly employed but which pertain merely to matters "electrical." (*Journal of Electricity.*)